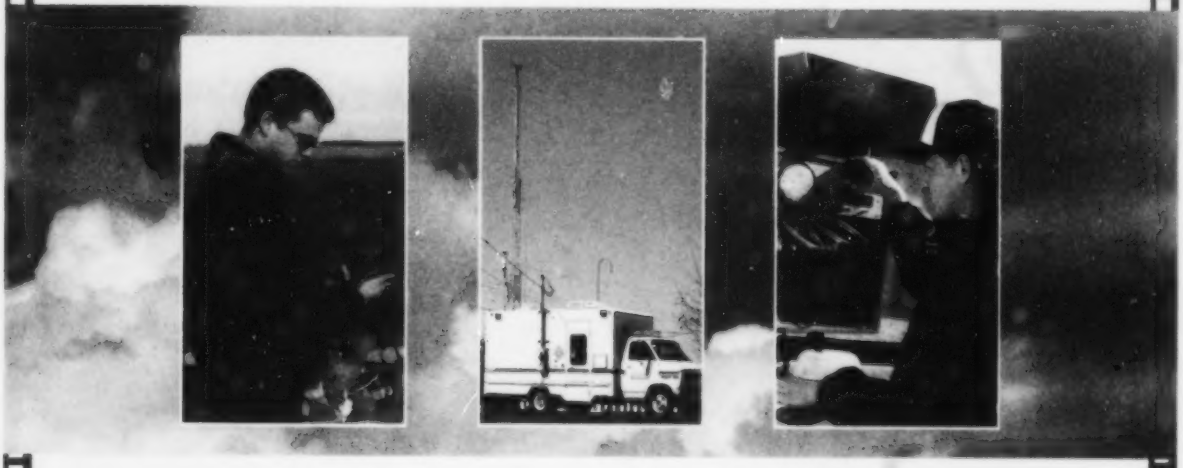
A REPORT ON

AIR QUALITY MONITORING RESULTS IN NEW BRUNSWICK

FOR THE YEAR 2001



Environmental Reporting Series

New Nouveau Brunswick
Environment and Local Government

104-00350/

New Brunswick Department of the Environment
and Local Government

New Nouveau Brunswick

NEW BRUNSWICK

AIR QUALITY MONITORING RESULTS

FOR THE YEAR

2001

Technical Report T-2002-02

Sciences and Reporting Branch
New Brunswick Department of the
Environment and Local Government
P.O. Box 6000
Fredericton
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Spring 2003

EXECUTIVE SUMMARY

This report summarises air quality monitoring data in New Brunswick for 2001. The report is intended to provide a convenient summary of air quality results for general public information, with emphasis on air quality assessment in relation to existing air quality standards and objectives. Long term trend data are also presented for representative sites. In New Brunswick, air quality standards for carbon monoxide, sulphur dioxide, hydrogen sulphide, nitrogen dioxide and total suspended particulate are specified in the *Air Quality Regulation* of the *Clean Air Act*.

Air quality has been monitored in New Brunswick since the 1960s, when several short-term studies were carried out in Saint John. The emphasis on air monitoring has steadily increased over the years. Air contaminants presently covered by provincial standards were measured at 53 sites in 8 regional monitoring networks across the province during 2001. Acid rain was measured at 13 additional sites. Inhalable particulate matter (PM_{10}), volatile organic compounds (VOCs) and mercury in air and precipitation were also monitored at some locations, although no standards were in effect in New Brunswick for these substances in 2001.

This report presents summary statistics from all monitoring sites in the province, with additional statistical data (in chart form) in an Appendix.

The results in this report show that compliance with standards was generally good in 2001, with 100% compliance at many locations, and few sites having compliance rates of less than 95% of the total number of hours measured. Some variation in results is evident between regions and their monitoring networks. This variability is due to many factors including emissions trends, variations in industrial output, changing process or emission control technologies, and the weather conditions experienced in the year.

The average compliance with established air quality standards remained greater than 99% in 2001. There were no exceedances of standards for nitrogen dioxide or carbon monoxide at any of the provincial monitoring sites (nine sites for nitrogen dioxide and three for carbon monoxide). Exceedances for sulphur dioxide were similar or lower than 2000, whereas ozone exceedances were significantly higher. Exceedances of hydrogen sulphide and particulate matter were significantly lower than in 2000.

Episode control programs, which are in effect for some major emission sources across New Brunswick, were seen to be effective in reducing the number of occasions on which elevated levels of air pollutants occur. Notable in this regard is the program in place in Saint John, which has enabled almost 100% compliance with a very strict ambient standard for sulphur dioxide. The New Brunswick Department of the Environment and Local Government (NBDELG) continually works with industries to implement the necessary control technologies to ensure compliance with air quality standards.

An examination of air quality trends at sites with long records indicates that since the late 1970s and 1980s, air quality has improved for all pollutants currently being measured, with the possible exception of ground level ozone, for which no clear trend is apparent. Levels of sulphur dioxide, total suspended particulate, and PM_{10} have fallen significantly over the past 15-20 years. Levels of carbon monoxide and nitrogen dioxide have also generally fallen. Total VOC concentrations in 2001 increased at both Forest Hills and Champlain Heights, compared with 2000.

Although acid deposition has generally declined since the early 1990s, acid rain impacts continue to be of concern in the province, particularly in southwestern districts. Sulphate in precipitation, a key indicator of acid rain, was slightly lower in 2001 than in 2000, although readings remained close to the average for the past 5 years.

Mercury in precipitation has fallen slightly since 1996. There was little evidence of any trend for mercury in ambient air over the same time period.

During 2001, NBDELG developed and began using a mobile air quality monitoring vehicle. The unit was sited in Saint John and Miramichi to investigate conditions in locations not covered by permanent monitoring sites. Generally low pollutant levels were found, with the exception of sulphur dioxide in the Grandview Industrial Park in east Saint John. A number of exceedances of standards for sulphur dioxide were logged at that location, and assessment continues.

New Brunswick is continuing its active dialogue, information-sharing, data analysis and policy activities with neighbouring provinces and US states, to make further progress on both ground level ozone and acid rain abatement.

The management of air quality in New Brunswick is based upon the principles set out in the *Clean Air Act*. The Department's goal is full compliance with regulatory standards, and the prevention of degradation of air quality in the province.

Feedback

We are interested in your opinions and feedback on this report. All suggestions will be considered, and if possible, incorporated in future reports. You may contact the Sciences and Reporting Branch at (506) 457-4844, by fax at (506) 453-2265 or e-mail Robert Hughes at robert.hughes@gnb.ca with any comments.

Technical terms

Efforts have been made to keep the number of technical terms used in this report to a minimum. A list of common technical terms are defined or explained in a Glossary of Terms, which begins on page 73.

Acknowledgements

Numerous staff within NBDELG and from the industries operating monitoring networks provided valuable help with data provision. Special thanks to Stan Howe and Eric Blanchard of NBDELG for operation of the provincial monitoring sites, and the staff of the Saint John regional office of NBDELG for assistance with site operation in the Saint John area. Thanks to Sean Fortune for operation of the acid rain network and assistance with emissions data. Thanks also to Karen Pelletier of NB Power for her help with the acid deposition network.

Thanks to Elizabeth Hayward and Randy Piercey for reviewing the report, and to Matthew Dickson for help with data analysis and chart creation.

Thanks are also extended to site operators in the provincial acid rain monitoring network, including Alphonse Boissoneault (St. Maure), Marielle Morisette (Canterbury), Marie-Jeanne Cormier (Paquetville), Daniel Boudreau (Robertville), Jeffrey Suttie (Pennfield), Robbie and Aubrey Parish (Nictau), Murray MacFarlane (Holtville), Wanda and Bart Petley (Harcourt), Lori Lawlor (Lakewood Heights), Mae Stewart (Trout Brook), Gary and Nancy Kierstead (Coles Island), Luanne Brawn, Markle Brawn, Glen Eastwood, Robin Mazerolle, (South Oromocto Lake) and Thane Watts (Fundy Park).

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1. INTRODUCTION

This report summarises air quality information gathered during 2001 at monitoring locations across New Brunswick. A summary of data from the provincial acid rain network is also included. This report focuses on ambient (i.e. outdoor) air, which provides an indication of environmental quality in terms of air pollution. Some basic information on the emission of air contaminants is contained in section 9.
Air quality has been monitored in New Brunswick since the 1960s, when several short-term studies were carried out. A number of federal and provincial agencies were involved in these co-operative projects, including the N.B. Department of Health. The New Brunswick Department of the Environment was established in 1971. Following this, more routine air quality monitoring began in areas known to be affected by industrial emissions. The accompanying box details a number of significant events in the history of air quality assessment in the Province.

In 1973 the permitting provisions of the first *Air Quality Regulation* took effect, whereby facilities releasing contaminants to the environment could do so only in accordance with terms set out in an Approval to Operate.

AIR QUALITY MILESTONES IN NEW BRUNSWICK 1961-1979

DATE	EVENT
1961	Smoke and hydrogen sulphide monitoring carried out in Saint John by Transport Canada.
1964	Particulate pollution in Saint John studied by the Department of National Health and Welfare.
1970	Saint John District Medical Health Officer (DMHO) requested a federal study on air quality in the city.
1970	Dustfall and sulphur dioxide assessment began around the Belledune lead-zinc smelter.
1971	A five-week study of hydrogen sulphide, particulates and sulphur dioxide carried out in Saint John in response to the request of the DMHO.
1971	New Brunswick Department of Fisheries and Environment formed.
1971	Environment Canada, the federal environmental protection agency, established. The National Air Pollution Surveillance Network begins operation.
1971	New Brunswick Clean Environment Act entered force. National Air Quality Objectives proposed.
1973	The first provincial Air Quality Regulation enacted, including smoke density standards, a permit process for operations emitting air pollution, and limits on the sulphur content of fuel oils.
1974	Two-way catalytic converters required for new motor vehicles, to control carbon monoxide and hydrocarbon emissions.
1975	Extensive vegetation injury from air pollution seen in Saint John in July. Monitoring networks reviewed and improved.
1976	A computerised data collection system set up to gather data from air pollution monitors in Saint John.
1978	Air quality monitoring initiated around the Dalhousie thermal generating station.
1979	The issuing of a twice-daily air quality index system (Index of the Quality of the Air, or IQUA) began in Saint John.
1979	The Air Quality Regulation revised, with the inclusion of ambient air quality standards for the first time.

By the late 1970s, emphasis was also being placed on providing air quality monitoring information to the public. In 1979, an air quality index for public information was introduced in Saint John. The "IQUA" program - (Index of the Quality of the Air) was the first program of its kind to be operated in any Canadian municipality.

2. WHAT'S NEW

New in the provincial air report this year:

- results from the department's mobile air quality monitoring unit.

AIR QUALITY MILESTONES IN NEW BRUNSWICK 1980-2001

DATE	EVENT
1980	The IQUA index reached the very poor range during a serious episode in Saint John in late July and early August, featuring high levels of sulphur dioxide and ozone.
1980	Air quality monitoring started in Edmundston to assess the impact of the Fraser pulp mill.
1987	Three-way catalytic converters required on new motor vehicles, which reduce emissions of nitrogen oxides, as well as carbon monoxide and hydrocarbons.
1987	New Brunswick signs acid rain reduction agreement with Federal Government.
1988	Air quality monitoring established around the Grand Lake thermal generating station.
1989	Monitoring begun in Miramichi around the REPAP paper mill (then the MPPC mill).
1990	Leaded gasoline banned.
1991	Air quality monitoring started around the thermal generating station at Millbank and future site at Belledune.
1993	The provincial *Clean Air Strategy* released, outlining long term plans for air quality protection, enhancement and management.
1993	The smog advisory program (joint program with Environment Canada) began in southern counties of NB, providing public forecasts of high ozone levels.
1995	Air Resource Management Area (ARMA) Committee established in Saint John. The sulphur dioxide standard in Saint John, Kings and Charlotte counties reduced by 50%.
1996	ARMA committees established in Edmundston and Bathurst.
1997	ARMA committees set up in Dalhousie/Campbellton and Miramichi. *Clean Air Act* received government assent.
1997	IQUA issued in Saint John three times daily and available on the Internet. Daily forecasts of ground-level ozone released to the media for Fundy counties of southern New Brunswick (joint program with Environment Canada).
1997	*Clean Air Act* came into force on December 15.
1998	Air quality monitoring site established in Moncton.
1999	IQUA index available hourly via dial-in phone service in Moncton, Saint John and Fredericton. Daily ozone forecasting expanded to central and eastern New Brunswick.
2000	Daily ozone forecasts issued province wide from May to October (joint program with Environment Canada).
2001	Mobile air quality unit brought into use.

3. AIR QUALITY LEGISLATION IN NEW BRUNSWICK

The basic framework for air quality management in New Brunswick is provided by the 1997 *Clean Air Act*. This Act broadly specifies the areas and activities in which the Minister of the Environment and Local Government has authority to make regulations.

In comparison to the *Clean Environment Act,* the *Clean Air Act* is more comprehensive and detailed legislation. It also places major emphasis on providing information to the public and encouraging opportunities for public involvement in decision-making.

Regulations are created under such Acts in accordance with the authority they provide, and set out the detailed requirements which must be followed by individuals or organisations who are subject to the legislation.

Since 1973, the *Air Quality Regulation* has been the Province's principal regulatory tool in this field and, with some recent revisions, it continues to apply under the *Clean Air Act*. It sets out detailed requirements and provisions for a wide range of air quality management issues. Provincial air quality standards have also been contained in this regulation since 1979.

Other regulations which are used to manage air quality cover issues such as Ozone Depleting Substances. As part of the more comprehensive *Clean Air Act*, additional regulations have been prepared, including the *Administrative Penalties Regulation* (which came into force in July 1998) and the *Public Participation Regulation* (which entered force in March 2002).

These regulations are aimed at providing the Province with additional options to promote compliance, and formalising procedures for public review of Certificates of Approval for major emission sources, as well as the process of setting or revising air quality objectives for the Province.

The *Clean Air Act* and its associated regulations are intended for the management of outdoor air quality. Air quality in buildings is regulated by health legislation, including the *Health Act* and the *Occupational Health and Safety Act*.

4. NATIONAL AIR QUALITY STANDARDS AND OBJECTIVES

Air quality management in Canada is primarily a provincial responsibility, although the Federal Government has a key mandate to carry out monitoring and research, as well as manage air issues which have a trans-boundary or international component. An example is the long range movement of air pollutants across provincial or international boundaries, such as those which cause acidic precipitation and ground level ozone.

Canadian air quality objectives are developed by a national committee (the Working Group on Air Quality Objectives and Guidelines) which includes representation from federal and provincial health and environment officials. When finalised through the Working Group process, the resulting "National Ambient Air Quality Objectives" are incorporated in federal legislation under the *Canadian Environmental Protection Act.*

The goal of this process is to ensure some degree of uniformity across the country. Provinces then have the opportunity to incorporate these national objectives in their own environmental legislation. A complete listing of Canada's existing National Air Quality Objectives is contained in Appendix II.

National Objectives cover the major air pollutants of concern. Individual provinces, however, are able to develop additional air quality objectives or guidelines, if deemed necessary for environmental management in their particular jurisdiction. An example of this would be New Brunswick's decision in 1995 to adopt ambient air quality standards for sulphur dioxide (SO_2) in the southern part of the Province (such as the one-hour level of 17 parts per hundred million), which are twice as stringent as the existing National Objectives for this substance.

Canada Wide Standards (CWS) are also being established for air, water, soils and sediments. The focus is on setting environmental quality standards which are based on sound science, with the aid of stakeholder public input. Other aspects of the CWS process include a consideration of socio-economic and technical issues as the standards are determined, the incorporation of an implementation plan for each standard, and a commitment for public reporting on the achievement of the standards. More information and updates are available at: http://www.ccme.ca/index.html.

The National Working Group on Air Quality Objectives and Guidelines periodically reviews the latest scientific work dealing with the effects of pollutants on human health, and the environment in general. Based on these reviews, the existing National Air Quality Objectives are revised as required. New objectives may also be proposed.

With the exception of the objective for ground level ozone, New Brunswick has included all National Air Quality Objectives in its *Air Quality Regulation* since 1979. This action has the effect of giving such objectives legal status through the *Air Quality Regulation's* approval process.

In the case of pollutants such as ground level ozone, the management approach in New Brunswick involves reducing the precursor emissions wherever possible, together with concerted regional control efforts, since the majority of ground level ozone measured in New Brunswick originates in the north-eastern United States and, to a lesser extent, southern Ontario and Quebec. This involves federally-led negotiations with States and Provinces which lie upwind from our western border. Precursor emissions are the substances which eventually lead to the formation of the pollutants themselves. For example, ground level ozone results from photo-chemical reactions in the air involving NOx (nitrogen oxides) and VOCs. In this case, NO_x and VOCs are precursors.

5. NEW BRUNSWICK AIR QUALITY STANDARDS

The New Brunswick *Air Quality Regulation* presently defines standards for five pollutants - carbon monoxide, nitrogen dioxide, sulphur dioxide, total suspended particulates and hydrogen sulphide. These numeric standards are indicated in the following table.

NEW BRUNSWICK AIR QUALITY STANDARDS				
Pollutant	Averaging period			
	1 hour	8 hour	24 hour	1 year
Carbon monoxide	30 ppm	13 ppm		
Hydrogen Sulphide	11 ppb		3.5 ppb	
Nitrogen dioxide	210 ppb		105 ppb	52 ppb
Sulphur dioxide*	339 ppb (34 pphm)		113 ppb (11 pphm)	23 ppb (2.3 pphm)
Total suspended particulate			120 micrograms/m^3	70 micrograms/m^3
* The standards for sulphur dioxide are 50% lower in Saint John, Charlotte and Kings counties.				

These figures are identical to Canada's National Air Quality Objectives, with the exception of the more stringent standards for sulphur dioxide in three southern N.B. counties, noted in the table above.

6. OTHER AMBIENT AIR QUALITY CRITERIA

A. Inhalable Particulate (PM_{10})

There is presently no National Objective for PM_{10} in Canada. Some existing standards in other areas are shown in the following table. These standards (primarily those from the Greater Vancouver Regional District and the U.S.A.) are currently used as reference points for evaluation of any PM_{10} data gathered in NB. Note: Newfoundland also adopted a 24-hour objective of 25 micrograms per cubic metre for $PM_{2.5}$ in 1997.

PM_{10} Standards in Various Jurisdictions (micrograms per cubic metre)

Jurisdiction (date)	Averaging period	
	24-hour	1 year
GVRD (Vancouver) (1994)	50	30
Newfoundland (1997)	50	-
United States (1987; revised 1997)	150	50
California (1982)	50	30
Australia (1998)	50	-

B. Ground Level Ozone

As with PM_{10}, there is no New Brunswick standard in effect for ground level ozone. For evaluation purposes, the existing National Objectives for ozone are used as a reference and are shown in the following table. Additional information on the National Air Quality Objectives is contained in Appendix II. Note that New Brunswick is participating in the implementation of Canada-wide standards for both $PM_{2.5}$, and ozone. In addition, New Brunswick provided input for the development of an Ozone Annex to the Canada-US Air Quality Agreement, signed in December 2000. The Annex formally recognises the geographic regions in Canada and the US where specific control measures must be applied to reduce ozone formation. It also deals with emission caps or ceilings; technical limits on certain industrial processes; scientific work such as data sharing, mapping and interpretation, and data reporting.

National Ambient Air Quality Objectives for Ozone (ppb)			
Averaging period	Desirable Level	Acceptable Level	Tolerable Level
1 Hour	51	82	153
24 hours	15	25	-
Annual	-	15	-

Note: for an explanation of the different levels, see Appendix II.

7. AIR POLLUTANTS - THEIR SOURCES AND EFFECTS

Basic information is presented in the following sections about the pollutants covered by regulatory ambient standards in New Brunswick. The sources of such pollutants are also discussed, as well as their effects on human health and the environment.

A. Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless and tasteless gas. Major sources include motor vehicles, home heating systems, and refuse burning. Outdoors, CO is generally a problem pollutant only in congested urban centres with high traffic density, especially in winter, as vehicle engines produce more pollution in cold weather. In some traffic conditions, drivers and passengers in vehicles may be exposed to higher levels of CO than pedestrians in city streets. Malfunctioning or badly-vented heating furnaces or stoves may also produce dangerous levels of CO in buildings.

If inhaled, CO quickly enters the blood stream, where it reduces the ability of the blood to deliver oxygen to the organs and tissues of the body. The health impact of CO is most serious for those who suffer from cardiovascular disease, although healthy individuals are also affected at higher concentrations. Exposure to elevated levels is associated with numerous symptoms, including headache, fatigue, nausea, and impairment of vision. Work capacity, learning ability and the ability to perform complex tasks are reduced (Stewart, 1975; USEPA, 1980; Ritchie, 1991; CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1994; 1998).

B. Nitrogen Dioxide

Nitrogen dioxide (NO_2) in high concentrations is a reddish gas with a sharp, pungent smell. It is corrosive and can assist the start and spread of fire. Most NO_2 found in the outdoor environment is not the result of direct emissions. Instead, it forms from nitric oxide (NO), which is emitted by many combustion sources, especially those which operate at high temperatures and pressures.

Motor vehicle engines meet both these characteristics, and are a major source of NO, which reacts quite rapidly with ozone in the air to form NO_2. Collectively, NO and NO_2 are often referred to as nitrogen oxides or NO_x. Thermal electricity generating stations and large heating boilers are other major sources of NO_x.

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection. It also has an adverse effect on materials (e.g. corrosion of metals, fading of fabric dyes, degradation of rubber, etc.) and can damage vegetation (CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1987a).

As noted earlier, NO_2 also plays an important role in the formation of ground-level ozone, by reacting with hydrocarbons in the presence of sunlight, and contributes to the formation of acid rain and visibility-reducing haze, or smog.

C. Sulphur Dioxide

Sulphur dioxide (SO_2) is a colourless gas with a characteristic smell, like that of a struck match. When levels reach between 0.3 to 1.0 parts per million (ppm), it is generally detectable as an acidic taste in the air. SO_2 dissolves very readily in water, eventually forming sulphuric acid. SO_2 is one of the most significant pollutants in many industrialised nations: it is often emitted as a result of burning sulphur-containing fuels, and by metal smelters and oil refineries. Emissions of SO_2 from motor vehicles are relatively minor.

Health effects associated with exposure to high concentrations of sulphur dioxide include breathing discomfort, respiratory illness, alterations in the lung's normal defences, and aggravation of existing respiratory and cardiovascular disease. People with asthma, chronic lung or heart disease are the most sensitive to SO_2. Apart from effects on human health, SO_2 can also directly damage the leaves of trees, and agricultural crops. (Environment Canada, 1985; CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1987b). SO_2 also has important indirect impacts by contributing to acid rain, which acidifies lakes and rivers, speeds up the corrosion of masonry and metal objects, and removes essential elements from the soil. Sulphur dioxide also contributes to the formation of acid aerosols (fine acidic particles), which may have detrimental health effects. These small particles cause a visual haze, which affects the enjoyment of scenic vistas and has an effect on the earth's radiation balance.

D. Hydrogen Sulphide

Hydrogen sulphide (H_2S) is a colourless gas with a characteristic smell of rotten eggs. H_2S is flammable and can form an explosive mixture with air or oxygen. Common sources of H_2S include pulp and paper mills, oil refineries, steel processing plants, natural gas plants, and sewage treatment systems. Natural sources include sulphurous hot springs and volcanic vents, swamps and bogs. Naturally-occurring sulphate-reducing bacteria can also produce H_2S in domestic water systems. The processes which produce hydrogen sulphide often generate other sulphur-containing compounds, such as methyl mercaptan and dimethylsulphide. These substances are also highly malodorous, and are often grouped together with hydrogen sulphide and referred to as total reduced sulphur compounds, or TRS.

In the ambient air, the undesirable effects of H_2S are generally felt in terms of a bad odour. The odour threshold for H_2S is generally 1-5 ppb, but can be lower for some individuals. There is some evidence that persistent exposure to unpleasant odours may have an significant effect on community health: review and monitoring of relevant health studies continues.

At higher concentrations (from 2 to approximately 100 ppm) hydrogen sulphide affects the mucous membranes, causing eye and throat irritation. Above this level H_2S becomes life-threatening as the sense of smell is impaired, removing the body's normal warning signal.

High concentrations of hydrogen sulphide can also cause paint discoloration and metal corrosion, and are damaging to plants (Environment Canada, 1984; Masters, 1997). Life-threatening levels, in excess of 300 ppm, can exist in underground sewer pipe systems and occasionally above ground near sewer manholes, in situations where sewer gases are released from underground piping. During drilling for oil and gas, blow-outs can also occur with the release of large quantities of H_2S.

Ambient concentrations in New Brunswick, even in the vicinity of large emission sources, seldom exceed 40 ppb (0.04 ppm).

E. Ground-Level Ozone

Ozone (O_3) is a reactive, unstable form of oxygen. In very high concentrations, it is a bluish gas. The characteristic sharp smell of ozone may be recognised around electrical equipment such as motors or arc welders, where it is formed by the high temperature electric spark. In the concentrations found in outdoor air, even in the most severe pollution episodes, ozone is both colourless and odourless. Ozone is not emitted directly from smokestacks and exhaust pipes, but is formed in the air from other pollutants, most importantly nitrogen oxides (NO_2) and hydrocarbons or VOCs (such as solvent and gasoline vapours).

Vehicle exhaust contains all the necessary compounds to produce ozone, and, as a result, cars and trucks are important contributors to ground level ozone concentrations. Industrial emissions of NO_x and hydrocarbons are also significant precursor emissions for ground level ozone.

Slow-moving air and strong sunshine greatly speed up the formation of ozone. As a result, ground level ozone is not typically a problem pollutant in the cooler months, but is likely to be more significant in hot, hazy summer weather. Such haze may build up over a period of days into a "photochemical smog". However, the yellow or brownish colour of such smog is usually due to nitrogen dioxide and fine chemical particles, not the ground level ozone itself.

Because the formation of ground level ozone depends on weather conditions, the severity of ozone pollution can be very variable from one year to the next. In New

Brunswick, significant ozone episodes occur on average about six times per summer, mainly affecting the southern part of the province. Much of this ozone originates from populated regions of the north-eastern United States, especially the Washington to Boston "corridor".

Ground-level ozone irritates the lungs and can make breathing difficult. Exposure to high concentrations can result in chest tightness, coughing and wheezing. Recent health research suggests there is no threshold concentration below which ozone does not affect human health. Ground level ozone can cause damage to agricultural crops which are ozone-sensitive, such as potatoes and tomatoes. It can also cause noticeable leaf damage in other species. Forest trees and other vegetation may be injured, or growth inhibited. Ozone also weakens rubber, and attacks metals and painted surfaces (Bates, 1980; Multistakeholder NOx/VOC Science Program, 1997c).

Ozone levels are often lower in city centres than in surrounding rural areas. This is because ozone reacts with nitrogen oxides, often found in relatively high concentrations in city cores due to emissions from motor vehicles. This effect is seen in Saint John, although to a lesser extent than in larger cities. A separate network of sites exists to assess rural ozone. The results from that network are discussed later in this report.

F. Total Suspended Particulate (TSP)

Particles in the air (also called "particulates" by air pollution scientists) may either be of natural origin or the result of human activity. Some common natural sources and types of particulates include wind-blown soil dust, forest fires, sea salt, volcanoes, and plants (which produce pollen and spores). Human activities which generate particles include fuel combustion (domestic and industrial) and any other burning (e.g. waste incineration or slash burning); travel on dirt roads, construction work, and mining and quarrying. Dust on road and work sites is often wetted down to control particulate emissions. Other kinds of particles form in the air when gases such as sulphur dioxide (SO_2) and nitrogen oxides (NO_x) react together. These particles are partly responsible for the yellowish "smog" sometimes seen over large cities.

"Total suspended particulate" (TSP) has been a standard pollution measurement for many years, obtained by drawing a large volume of air through a special filter. This method makes no distinction between natural particles, such as pollen and spores, and particles which are emitted from vehicles or smokestacks.

People with existing breathing complaints such as asthma, bronchitis or emphysema, are liable to be adversely affected by high concentrations of particulates (Wilson and Spengler, 1996; CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1998).

Particulates can also cause corrosion and soiling of metalwork or other materials, damage vegetation, and reduce visibility.

TERMS USED TO DESCRIBE PARTICLES AND HAZE

TSP: Total suspended particulates. A measure of particle concentration determined with a high-volume air sampler, which draws air through a filter over a 24-hour period. Includes particles with a wide range of sizes, up to 25-45 microns in diameter. TSP is normally measured on a nationally-standardised one-in-six day cycle.

PM_{10}: Particulate matter with an effective diameter of 10 microns or less. Also termed "inhalable particulates", as particles of this size are small enough to be inhaled via the mouth and some may enter the lungs.

$PM_{2.5}$: Particulate matter with an effective diameter of 2.5 microns or less, which bypasses filtration in the nose and may be deposited in the lungs. Also referred to as "respirable" particulate.

CoH: Coefficient of Haze. A relative measure of particle concentration determined by drawing air through a paper tape and measuring the change in light transmission of the tape.

Particles, particulates, aerosols: When referring to air quality, these terms are interchangeable, and refer to particles small enough to be transported some distance through the air. Most of these are less than 40 microns in diameter (roughly the size of pollen grains).

Fine particles: Particles with an effective diameter between 0.01 and 2 microns. Most particles forming as a result of industrial processes and combustion (natural or man made) are in this size range. Sometimes loosely used to refer to $PM_{2.5}$. Includes smoke particles.

Coarse particles: Particles with an effective diameter between 2 and 100 microns; includes PM_{10}. Much of the coarse particle load in the atmosphere is of natural (crustal) origin. Also includes pollen and spores.

G. PM_{10}

Particles smaller than 10 microns (a micron is a millionth of a metre, or a thousandth of a millimetre) are called PM_{10}, and are not filtered out of the air by the nose, throat and upper windpipe. As a result, these very small particles can enter the lungs where they may irritate or otherwise have an adverse effect on the delicate membranes and air sacs which absorb oxygen. Other toxic effects may occur, depending on the chemical make up of the fine particles. Because they can enter the lungs, PM_{10} particles are sometimes referred to as 'inhalable' particles, and are measured separately from TSP.

A number of recently published health studies have concluded that lung function, cardio-respiratory mortality, respiratory illness-related hospital admissions, and a variety of other health factors are related to ambient concentrations of PM_{10}. However, which particular aspect of the fine particles is causing these effects has not yet been fully resolved. Particle chemistry, and possibly acidity, may be important. As for ozone, there appears to be no lower concentration threshold below which health effects are not observed. Recent studies also suggest that particles have effects on the immune system (Wilson and Spengler, 1996; Blomberg, 1998).

In Canada, only the Greater Vancouver Regional District (GVRD) and the province of Newfoundland have a standard in place for PM_{10}, although work on developing a national objective is currently under way. In the United States, standards exist both nationally and in California, which has the same standard as the GVRD (see table on page 7).

H. $PM_{2.5}$

Another standard specification for measuring particulates is $PM_{2.5}$, which refers to particles equal to or smaller than 2.5 microns in size. These particles are thought to be of special significance in terms of health impacts, as they have a higher chance of entering and remaining in the lungs if inhaled, compared to PM_{10} or larger particles. They are sometimes referred to as 'respirable particles'.

Monitoring technologies have been introduced in recent years which allow the continuous measurement of PM_{10} or $PM_{2.5}$. These units provide continuous, unattended recording and electronic logging and reporting functions. These units are now installed and operating in Saint John (two sites), Fredericton, Bathurst, Moncton, and St. Andrews. In June 2000 an additional monitor began operation in Edmundston, maintained by Fraser Paper Inc.

I. Volatile Organic Compounds

VOCs are carbon-containing substances which are present in the air in gas form, usually at low concentrations (in the parts per billion range). Used in the context of air quality, VOCs are substances which often evaporate readily.

Thousands of different VOCs exist in the air. However, many VOCs are of natural origin, and in terms of environmental protection, the VOCs which cause some kind of problem are most important. Everyday examples of VOCs which may be a concern in the environment include gasoline and organic solvents. Other products such as paint, adhesives, and a variety of other household goods may contain solvents which evaporate and contribute to the VOC content of the air. VOCs are also emitted by a wide range of industrial sources, as well as by motor vehicles. Vehicles emit VOCs in their exhaust, and from fuel tanks. Modern vehicles have systems in place to minimize such emissions, but overall, transport-related emissions are still substantial. A large number of VOCs can be emitted by industrial processes (for example by the petrochemicals or plastics industries).

Some VOCs may be potentially toxic to humans, animals or vegetation (e.g. benzene, 1,3 butadiene, ethylene) or are of concern because they can react in the air to form other harmful substances. For example, ethylene and propylene (and many other VOCs) may take part in reactions which lead to the formation of ozone-containing smog. Some VOCs may contribute to undesirable odours, such as various petroleum hydrocarbons.

The VOC sampling program in New Brunswick concentrates on about 150 compounds which are of special interest, including known and suspected carcinogens such as benzene and 1,3 butadiene, and photochemically active VOCs which contribute to smog formation.

8. MONITORING NETWORKS

Compliance with air quality objectives or regulatory standards is determined by monitoring. Because exposure to many air pollutants can occur at any time, most are monitored continuously, although particulates have been an exception. However, new technology now allows continuous measurement. As a result, continuous particulate measurements are gradually becoming more widespread and available.

Monitoring locations are selected so that they will provide information which is representative of the surrounding area. In cases where there is a known pollutant source, monitors are often distributed around it in locations where the impact is expected to be greatest. Such locations are typically selected based on the results of computer dispersion models. These are computer programs which simulate the behaviour of plumes, or discharge streams of gases as they are released from smokestacks. Such models take into account the complete variety of weather conditions which may be experienced in the area where the stack is located, as well as the nature of the local landscape.

In New Brunswick, large industrial emission sources, such as electricity generating stations or pulp mills, are legally required by NBDELG to carry out ambient air quality monitoring as prescribed in their Approvals to Operate under the Clean Air Act. Such Approval conditions also detail the required equipment specifications, locations and reporting frequency. In such cases, the monitoring equipment and maintenance procedures are checked periodically by NBDELG staff or independent auditors, to ensure the required standards for operation and technical accuracy are being met.

In the case of air pollutants which are transported long distances, and which may be found in rural, as well as urban areas, NBDELG establishes and operates its own monitoring sites. The Department also maintains sites in areas where there are multiple large industrial emission sources, such as Greater Saint John. In addition to 13 provincial sites, there is one federally-operated acid rain monitoring site in New Brunswick (at Harcourt, in eastern New Brunswick). Federal support is also provided for the operation of several other air quality monitoring sites across the province (through the National Air Pollution Surveillance program).

The location of air quality monitoring sites and the main regional and local networks are shown on the following map (Figure 1). More detail on the exact location of each site is provided in the following sections.

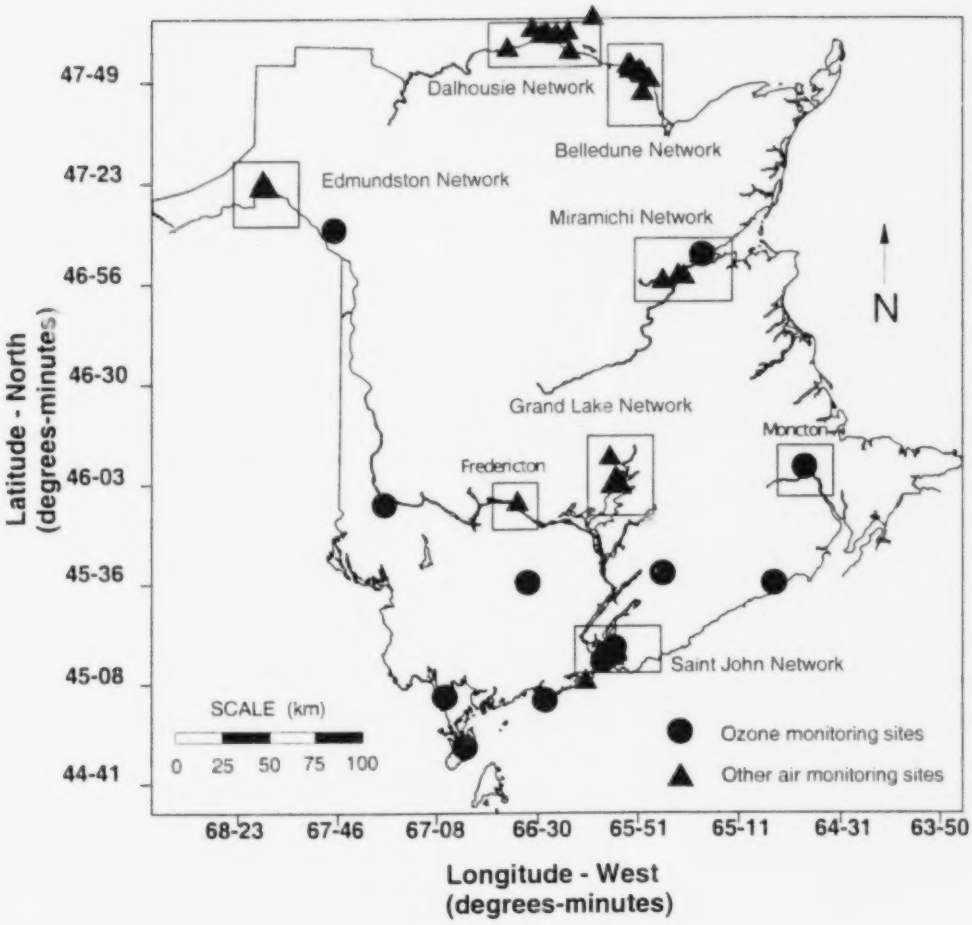

Figure 1. Locations of air quality monitoring sites in New Brunswick.

The major industry or urban networks are identified. Filled circles on the map indicate rural ozone sites. The remainder indicate ambient monitoring locations for other substances including sulphur dioxide, nitrogen dioxide and particulates.

9. EMISSIONS OF AIR POLLUTANTS

A summary of the principal air pollutants and their source categories is provided in this section. These figures are based upon routine reports supplied to NBDELG by industries, as well as upon estimates calculated from engineering data and published emission factors.

2001 EMISSIONS - NEW BRUNSWICK					
Source Category	Emissions in tonnes per year				
Industrial Sources	Particulate matter	SOx	VOC	NOx	CO
Electric power generation	2 050	110 398	26 254	1 703	262
Other commercial fuel combustion	135	366	96	70	22
Pulp mills	1 701	10 693	2 254	2 102	685
Other wood industry	495	802	259	762	77
Petroleum refining	435	5 591	4 363	1 678	168
Other chemical industries	30	0	62	6	0
Mining and smelting	179	12 138	230	21	1
Transportation	1 900	2840	40 330	118 760	14 280
TOTAL	6 925	142 828	15 495	73 848	125 102

Notes: SOx = SO_2 plus SO_3; NOx = NO plus NO_2. Transportation figures are estimates for 1995, source: Environment Canada. VOC = volatile organic compound.

The results are divided into two main categories: industrial sources, and transportation. Industrial sources include major installations such as power generating stations, oil refineries, pulp mills and metal smelters. In such situations, air pollution is typically emitted from a small number of chimney stacks at relatively high rates. In contrast, the transportation category includes domestic and heavy-duty vehicles, plus air, marine and rail emissions. In this category, emissions are usually released at lower rates, spread out over a large area.

In addition to these categories, there are also significant emissions from other sources such as construction, domestic wood burning, and emissions from open sources such as forest fires and dust from roads. **Note that estimates for these categories are not included in the totals given in the table**. Accordingly, the totals here may differ from those quoted elsewhere. The emissions data given here are not intended to be comprehensive. Data are presented for selected sectors to provide a basic understanding of emissions in the major industrial categories, plus transportation. Work is ongoing to improve the accuracy of emissions estimates from all sources. Details of this work can be found on the internet at: http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm.

In 2001, industrial emissions of sulphur oxides (SOx) rose by about 10% from 2000, due to an increase in emissions from the utility and pulp mill sectors. Nitrogen oxide emissions rose about 5%. Emissions of particulates were little changed. Estimated emissions of VOCs and CO were substantially down, due to a combination of improved fuels and upgraded vehicle emission standards. VOC emissions were estimated to be 36% lower than in 2000, and CO emissions, 41% lower.

Information to enable detailed, up to date interprovincial comparisons of air pollutant emissions is not readily available. Some information may be obtained from the web site mentioned in the previous paragraph. In general, New Brunswick emissions are approximately 3%-5% of national totals for most substances. Additional information on air pollutant emissions in New Brunswick may be found in other reports (e.g. Delauriers, 1995; Environment Canada, 1998; Jaques, 1997) or by contacting DELG using the contact details provided on page iii.

10. AIR QUALITY MONITORING RESULTS FOR 2001

This report contains information for 2001. Results are presented for each monitoring network in the Province. The locations of the monitoring sites are shown on regional scale maps. The numeric results are shown in tables, and further details in chart form appear in Appendix III.

Explanatory notes are provided on each network, and a discussion of the results for each network is included.

A. SAINT JOHN

The Saint John area has the longest history of air quality monitoring in New Brunswick, beginning in 1961 (see boxes on pages 1-2). Since that time, air quality has been monitored at more than 30 different locations in the city and surrounding area. Air quality monitoring sites which are presently active (a total of 12 separate locations) are shown on the following map (Figure 2).

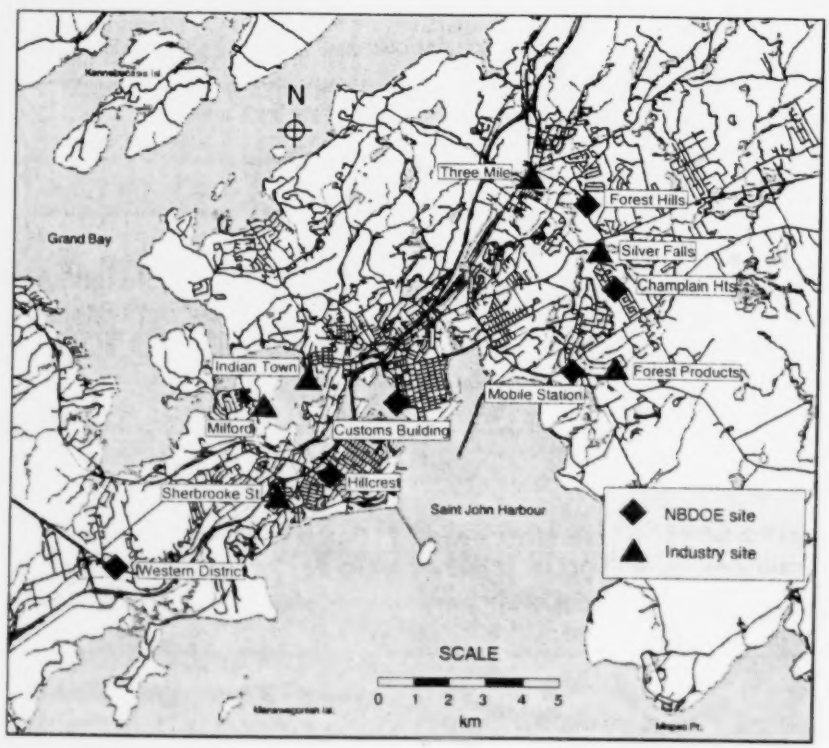

Figure 2. Air quality monitoring sites in Saint John, New Brunswick.

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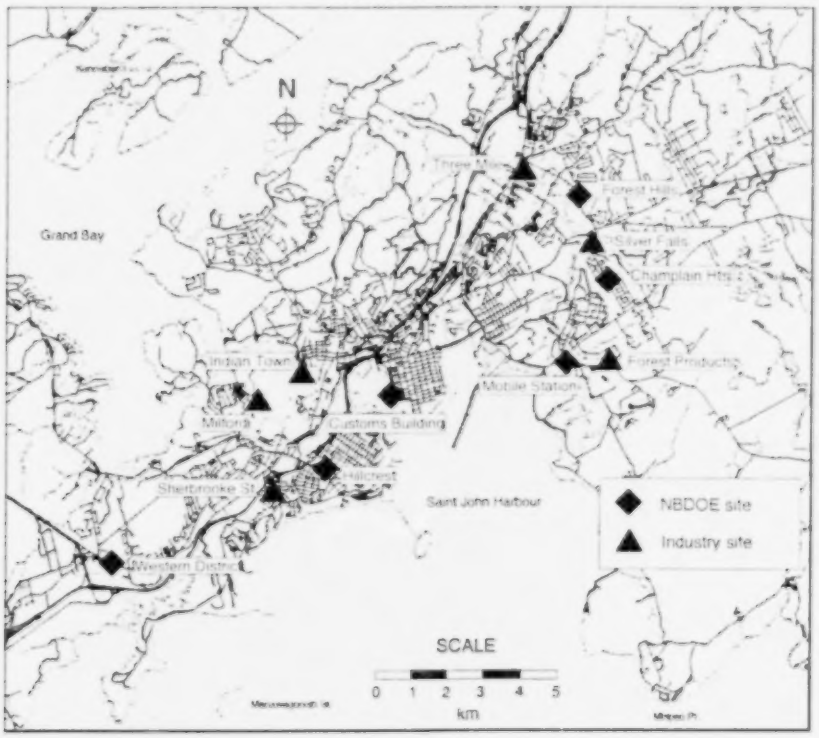


Figure 2. Air quality monitoring sites in Saint John, New Brunswick.

Most of these sites are electronically linked to a central computer at the NBDELG regional office in Saint John. This system communicates with the monitors a minimum of once each hour and obtains the latest readings. These are then added to the existing data archive and are used to prepare IQUA public information messages, as well as to determine the nature of any abatement actions required by industries if concentrations rise above pre-determined trigger points. Such episode control systems are specified in various Approvals to Operate issued to major emission sources by the Department.

On the City's west side, three monitoring sites for hydrogen sulphide are operated by Irving Pulp and Paper Ltd. NBDELG also operates a site at the Hillcrest Baptist Church off Lancaster Avenue, at which sulphur dioxide, hydrogen sulphide, ozone and PM_{10} are monitored, and another site on Manawagonish Road, for PM_{10} only. In east Saint John, three sites for sulphur dioxide and one for $PM_{2.5}$ particulate matter are operated by Irving Oil Ltd, as required by the company's operating approval, and results are sent electronically to the Department's data system.

NBDELG also maintains sites at Forest Hills and Champlain Heights in the eastern suburbs, and at the Customs building in the uptown area. The Customs site has monitors for ozone, sulphur dioxide, nitrogen dioxide and carbon monoxide. At Forest Hills there are monitors for ozone, sulphur dioxide, nitrogen oxides, PM_{10}, $PM_{2.5}$ and volatile organic compounds. At the Champlain Heights School, sulphur dioxide, nitrogen dioxide, VOCs and $PM_{2.5}$ are measured.

A.1 Carbon Monoxide

This pollutant is monitored at the Customs Building site to provide data representative of the city centre. Peak hourly values in every month were well below the applicable standard of 30 ppm in 2001. There were also no exceedances of the 8-hour standard of 13 ppm.

A.2 Nitrogen Dioxide

There were no exceedances of the 1-hour standard of 210 ppb at either the Forest Hills or Customs Building monitoring sites in 2001. Neither were the 24-hour standard (105 ppb) or the annual standard (52 ppb) exceeded.

A.3 Sulphur Dioxide

During 2001 there were exceedances of the 1-hour or 24-hour standard at two sites in the network, Champlain Heights and Silver Falls. Details are shown in the following table. There were no exceedances of the annual standard at any site.

Exceedances of the 1-hour sulphur dioxide standard in 2001 Saint John (number of hours)													
Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Forest Hills	0	0	0	0	0	0	0	0	0	0	0	0	0
Champlain Hts	0	0	1	0	0	0	0	0	0	0	0	0	1
Hillcrest	0	0	0	0	0	0	0	0	0	0	0	0	0
Customs	0	0	0	0	0	0	0	0	0	0	0	0	0
Three Mile	0	0	0	0	0	0	0	0	0	0	0		0
Forest Products	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver Falls	0	0	0	1	2	0	1	0	0	0	0	0	4
Total	0	0	1	1	2	0	1	0	0	0	0	0	5

The 1 hour standard is 17 pphm, which is equivalent to 170 ppb.

Exceedances of the 24-hour sulphur dioxide standard in 2001 Saint John (number of hours)													
Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Forest Hills	0	0	0	0	0	0	0	0	0	0	0	0	0
Champlain Hts	0	4	0	0	0	0	0	0	0	0	0	0	4
Hillcrest	0	0	0	0	0	0	0	0	0	0	0	0	0
Customs	0	0	0	0	0	0	0	0	0	0	0	0	0
Three Mile	0	0	0	0	0	0	0	0	0	0	0	0	0
Forest Products	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver Falls	0	0	0	0	0	0	47	0	0	0	0	0	47
Total	0	4	0	0	0	0	47	0	0	0	0	0	51

The 24-hour standard is 6 pphm, which is equivalent to 60 ppb.

A.3.1 Sulphur Dioxide Episode Control

An episode control program is in place to prevent ambient sulphur dioxide reaching undesirably high levels in Saint John. Control actions are initiated by major industries in the city in response to measurements made at the fixed monitoring sites.

As noted earlier, these control actions are made mandatory by being incorporated into the relevant Approvals to Operate issued by NBDELG. The episode control plans themselves are subject to continual review. NBDELG meets regularly with staff of the major industries in the city to review compliance in respect of sulphur dioxide.

Tables of Exceedances – What they Mean

The numbers in the tables of exceedances show the number of occasions when readings were above the standard. For example, the one hour standard for sulphur dioxide in Saint John is 170 ppb. Any hourly period when the measured value was higher than 170 ppb counts as one exceedance of that hourly standard. A 31-day month has 31 x 24 = 744 hours, so the maximum possible number of hourly exceedances for the month would be 744. If that happened, compliance would be 0%. Conversely, with no exceedances, compliance would be 100%.

Where 24-hour standards exist (as for SO_2 and H_2S), compliance is calculated using a running 24 hour average. In other words, not just individual 24 hour calendar days are considered, but every possible 24 hour period in each month, e.g. the 24 hours ending at 10 am on the 5th, the 24 hour period ending at 11 on the 5th, and so on for the whole period in question. Each hour, the 24 hour average is recalculated.

Any hour that the calculation is made and the result is over the 24-hour standard, counts as an exceedance. There could be up to 744 exceedances in a 31-day month. Because a 24-hour average tends to rise and fall gradually, compared to an hourly reading, the total number of 24-hour exceedances is almost always greater than the number of 1-hour exceedances.

All exceedance events are examined in detail and any shortfalls in the nature and extent of response action are addressed. NBDELG staff sometimes request emission control actions separate from or in addition to those specified in the response plans. Such action may be warranted due to unusual conditions, such as poor dispersion, or during periods when smog advisories are in effect.

Some of the ways in which industries respond to rising levels of sulphur dioxide include switching to lower or near-zero sulphur fuels, and reducing production rates or electricity generating rate. Response action is begun when monitored concentrations reach 80 parts per billion, approximately half the 1-hour standard of 170 parts per billion.

A.4 Ground Level Ozone

Ozone was monitored at three sites in the city during 2001: Forest Hills, the Customs Building and in west Saint John at Hillcrest Church. During 2001 there were 6 exceedances of the 1-hour National Ambient Air Quality Objective for ozone of 82 ppb in the Saint John Network, 2 hours at the Customs site and 4 at Hillcrest. Statistics were also calculated in reference to the Canada-Wide Standard (CWS) for ozone, which is based on an 8-hour averaging period and is set at 65 parts per billion. There was a total of 13 hours in excess of this value at the Customs site, and 90 hours at Hillcrest. New Brunswick (and other provincial governments) have committed to be in compliance with the new CWS for ozone by 2010. In the interim, CWS compliance statistics are calculated and presented for general assessment purposes.

Further details on ground level ozone follow in section 11, where complete results for all ozone monitoring sites are summarised.

Ozone is an air pollutant which can travel long distances, especially when winds carry the ozone over water (an example is transport from the Boston area to New Brunswick over the Gulf of Maine and Bay of Fundy). Years of monitoring, modelling and trajectory analysis have shown that the vast majority of ground level ozone observed in New Brunswick originates in the north-eastern United States. As part of the new CWS process, emission reductions will be pursued in this source area. Additionally, emission control plans are being prepared to address the ground level ozone issue within New Brunswick and other provinces.

A.5 Particulate matter

A.5.1 PM_{10} High Volume Sampler

NBDELG operates high volume samplers at four sites in Saint John (Forest Hills, Provincial Building, Hillcrest and Western District Police) which are specially modified to provide data on PM_{10}. As noted earlier, there is no Canadian National Objective presently in place for PM_{10}, and no provincial standard in New Brunswick. For evaluation purposes, reference is made to the standards in place in Greater Vancouver, the United States, and the State of California (page 7).

There were technical problems with the samplers at the Western District and Provincial Building sites during 2001 and no valid data were obtained. The Forest Hills and Hillcrest sites operated for approximately 30% of the year. There were no exceedances of the California/GVRD 24-hour standard of 50 micrograms per cubic metre at either location.

A.5.2. PM_{10} (TEOM)

PM_{10} was measured during 2001 at Forest Hills using a continuously recording TEOM instrument. Continuous recording provides complete coverage for all hours in the year, as opposed to the 1 in 6 day schedule used nationally for high volume samplers.

The 2001 results comprised over 7,500 hours, or about 86% of the year. Hourly peak values were typically around 80-90 micrograms per cubic metre during most months. Some jurisdictions have a standard of 50 micrograms per cubic metre for PM_{10}, averaged over 24 hours. This value was exceeded for a total of 33 hours during 2001.

A.5.3 $PM_{2.5}$ (TEOM)

A TEOM device measuring $PM_{2.5}$ was operated at Forest Hills in 2001. Valid data were logged for over 70% of the total hours of the year. There were a few hourly peaks of over 50 micrograms per cubic metre, and one event in October when concentrations exceeded 90 micrograms per cubic metre for a few hours. The Canada-Wide Standard for $PM_{2.5}$ is 30 micrograms per cubic metre as a 24-hour average, itself averaged over 3 years (see box). In 2001, there were 115 hours exceeding the 24-hour average of 30 micrograms per cubic metre. The 98th percentile reading for the year was 29.8 micrograms per cubic metre.

New Canada-Wide Standard for $PM_{2.5}$: Determining Compliance

Determining compliance with the Canada Wide Standard for $PM_{2.5}$ requires a number of calculations. From all the daily 24-hour averages for the year, the value is computed which is greater than 98% of all the readings. In other words, only 2% of the readings exceeded this value during the year. This is the 98th percentile value. A site is considered in compliance if the average of the 98th percentile values over three consecutive years is below 30 micrograms per cubic metre.

A.6 Hydrogen Sulphide and Total Reduced Sulphur

Hydrogen sulphide and total reduced sulphur (TRS) are often treated together. These air pollutants are monitored at the Hillcrest site (NBDELG) as well as three sites operated by Irving Pulp and Paper (Milford, Indian Town and Sherbrooke St.).

There were a number of exceedances at these sites in 2001, as indicated in the following table. As a percentage of total hours, compliance was greater than 92% at all sites for both standards.

Exceedances of standards for Hydrogen Sulphide in 2001
Saint John (number of hours)

1-hour standard (11 ppb)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hillcrest	0	0	0	0	0	0	0	0	0	0	0	0	0
Sherbrooke	0	0	0	0	3	6	0	0	0	0	0	0	9
Milford	0	0	0	0	0	1	0	0	0	0	0	0	1
Indian Town	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	3	7	0	0	0	0	0	0	10

24-hour standard (3.5 ppb)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hillcrest	0	0	0	0	0	0	0	0	0	0	0	0	0
Sherbrooke	0	0	0	0	372	312	0	0	0	0	0	0	684
Milford	0	0	0	0	0	5	0	0	0	0	0	0	5
Indian Town	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	372	317	0	0	0	0	0	0	689

A.7 Volatile Organic Compounds (VOCs)

VOCs have been measured at Forest Hills in east Saint John since 1992. Measurements have also been made for the same period of time at Point Lepreau, approximately 40 km southwest of the city. The Lepreau site is predominantly upwind of Saint John and serves as a control or reference site, representative of rural southern New Brunswick. In July 2000, VOC sampling was begun at Champlain Heights in east Saint John. The monitoring program for VOCs is a collaborative one between NBDELG and Environment Canada. NBDELG staff maintain the monitoring sites and set up the equipment to take samples (normally every 6 days). Environment Canada performs the analyses on the collected air samples.

Sites in Saint John collect one 24-hour sample every 6 days and the rural site at Point Lepreau collects a 4 hour sample beginning at noon, every 3 days. All samples are analysed for over 150 compounds, including VOCs which are involved in the formation of ozone, as well as VOCs which may be of interest for other reasons. For example they may be indicators of various kinds of industrial activity, or they may be potentially of concern in their own right (for example substances which are known to be potentially carcinogenic, such as benzene). Some other VOCs which are measured are found at similar concentrations regionally or even globally (such as several CFC compounds). These substances are of key interest in atmospheric research.

There are no ambient air quality standards for VOCs in Canada. Results can be compared against guidelines published by other agencies, and examined over time to look for trends, as well as differences between sites.

The table on the following page lists results for 2001 for selected VOCs, compared with guidelines recommended by various agencies. This subset of VOCs contains compounds which have traditionally been classified as "air toxics", and which are considered potentially harmful to human health. The first line of the results table also shows the average concentration taking into account all VOCs measured at each site (total VOC). Results from the new sampling location at Champlain Heights were similar to, or in some cases higher than, those measured at Forest Hills. Both sites had higher concentrations of most VOCs than the Point Lepreau site.

For the selected VOCs for which guidelines could be referenced, concentrations at both monitoring sites were found to be below these targets at both sites, in most cases by a substantial margin. The annual guideline for benzene recently published in the United Kingdom (5 ppb) has a compliance target date of 2003, with the long-term target being a guideline of 1 ppb (EPAQS, 1994, HMSO, 2000). Benzene is emitted from motor vehicles and is a component of gasoline. In Saint John, the petroleum refinery and other industries would also contribute to ambient concentrations, which were close to the Swedish guideline of 0.4 ppb. Additional analysis of VOC data is included in the section on long-term trends (section 13).

2001 VOC Monitoring Results							
VOC	Max 24-h averages (ppb)		24-h guidelines (ppb) (WHO)	Annual averages (ppb)			Annual Guidelines (ppb)
	Forest Hills	Champlain Hts		Forest Hills	Champlain Hts	#Point Lepreau	
Total VOC	107.9	241.6		46.1	64.5	5.6	
1,3 butadiene	0.26	0.11		0.06	0.04	0.0	1 (UK)
Benzene	1.15	2.16		0.45	0.68	0.07	5(UK) 0.4 (Sweden)
Toluene	5.56	4.2	63*	1.13	1.6	0.06	10-100 (Sweden)
Ethylbenzene	0.35	0.81	4464*	0.13	0.29	0.02	
Xylenes	0.97	2.21	1013	0.36	0.8	0.03	
Styrene	0.09	0.03	56*	0.02	0.02	0.01	
Chloromethane	0.67	0.63		0.58	0.55	0.52	
Vinyl chloride	0.01	0.01		0.01	0.01	-	
1,1 dichloroethylene	0.02	0.02		0.02	0.02	-	
Dichloromethane	0.14	0.32	792	0.08	0.09	0.09	100-250 (Sweden)
1,2 dichloroethane	0.03	0.04	159	0.02	0.02	0.01	100-150 (Sweden)
Carbon tetrachloride	0.11	0.12		0.1	0.1	0.1	
1,2 dichloropropane	0.01	0.01		0.01	0.01	-	
Trichloroethylene	0.02	0.02		0.01	0.01	0	100-200 (Sweden)
1,1,2 trichloroethane	0.01	0.01		0.01	0.01	0.0	
Ethylene dibromide	0.01	0.01		0.01	0.01	-	
Tetrachloroethylene	0.08	0.09	34	0.02	0.02	0.01	
1,1,2,2 tetrachloroethane	0.01	0.01		0.01	0.01	-	
Formaldehyde	4.25	-		2.55	0.0	-	
Acetaldehyde	1.76	-		1.0	0.0	-	

Notes: The guidelines marked with an asterisk (*) are for a weekly period.
Sources: WHO (World Health Organisation): 1987, 1994,1996 & 1997; Swedish standards: OECD, 1995. UK standards: HMSO, 2000. # Data at Pt Lepreau are collected for 4 hours each sample day, starting at noon AST. The other sites are based on 24-h samples every 6th day.

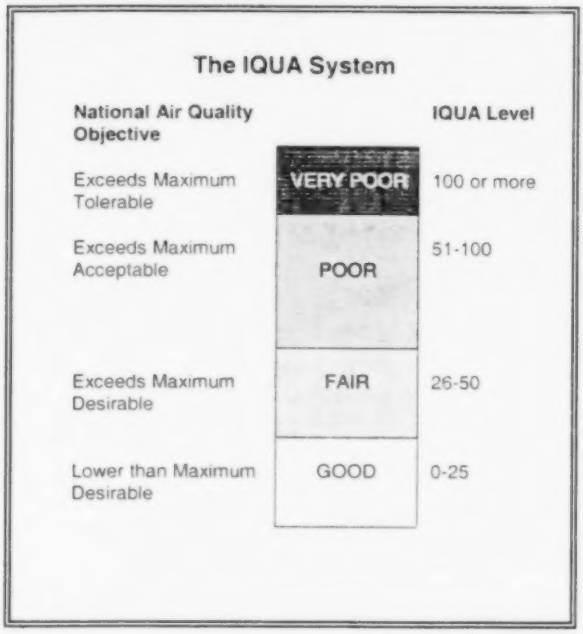
A.8 Index of the Quality of the Air (IQUA)

The IQUA system has been used in Saint John for over 20 years to help make air quality monitoring results easier to understand. Results for each pollutant measurement are expressed on a scale from 1-100, and classed as "good" (index 0 to 25), "fair" (26 to 50), "poor" (51 to 100) or "very poor" (over 100). Each of the categories is based on the National Air Quality Objectives listed in Appendix II. For example, "good" air quality indicates that pollutants are in the "desirable" range as defined by the air quality objectives. Values in the "fair" range are above the desirable, but below the acceptable objective. IQUA information is distributed daily via the NBDELG web site:

http://www1.gnb.ca/0355/0003/0000.asp

This web page is updated three times per day. IQUA information is also accessible by phone via recorded message (dial 636 4991 in the Saint John area). The recorded message is updated hourly.

For each hour, the IQUA index is computed for each pollutant measured at the site. The value reported is the highest of each of the individual values. For example if two pollutants are in the "good" range and one is in the "poor" range, then the index for the hour would be reported as "poor". In addition, the pollutant responsible for determining the overall index value is usually identified.



Summary statistics are given in the following table for the three designated IQUA sites in Saint John: Customs Building (uptown), Forest Hills (east) and Hillcrest (west). The table shows the number of hours logged in each IQUA category. It is apparent that the vast majority of the time, air quality was in the "good" category during 2001 (from 96 to 99% of the time). The percentage of hours in the "fair" range was less than 4% at all sites, and there were no hours recorded in the poor or very poor categories.

IQUA Summary 2001: Saint John Sites				
	Good (0-25)	Fair (26-50)	Poor (51-100)	Very Poor (over 100)
Forest Hills	99.4	0.6	0	0
Customs	99.0	1.0	0	0
Hillcrest	96.3	3.7	0	0

B. MIRAMICHI

There are two monitoring sub-networks in the Miramichi region, one centred on the UPM pulp mill emission sources, and the other on NB Power's Millbank gas turbine generating site. Pollutants of concern in these networks include hydrogen sulphide and particulates (UPM) plus nitrogen dioxide and sulphur dioxide (Millbank). Particulates are also measured at two sites operated by the Weyerhaeuser Company.

Figure 3 shows the locations of the five sites in the region.

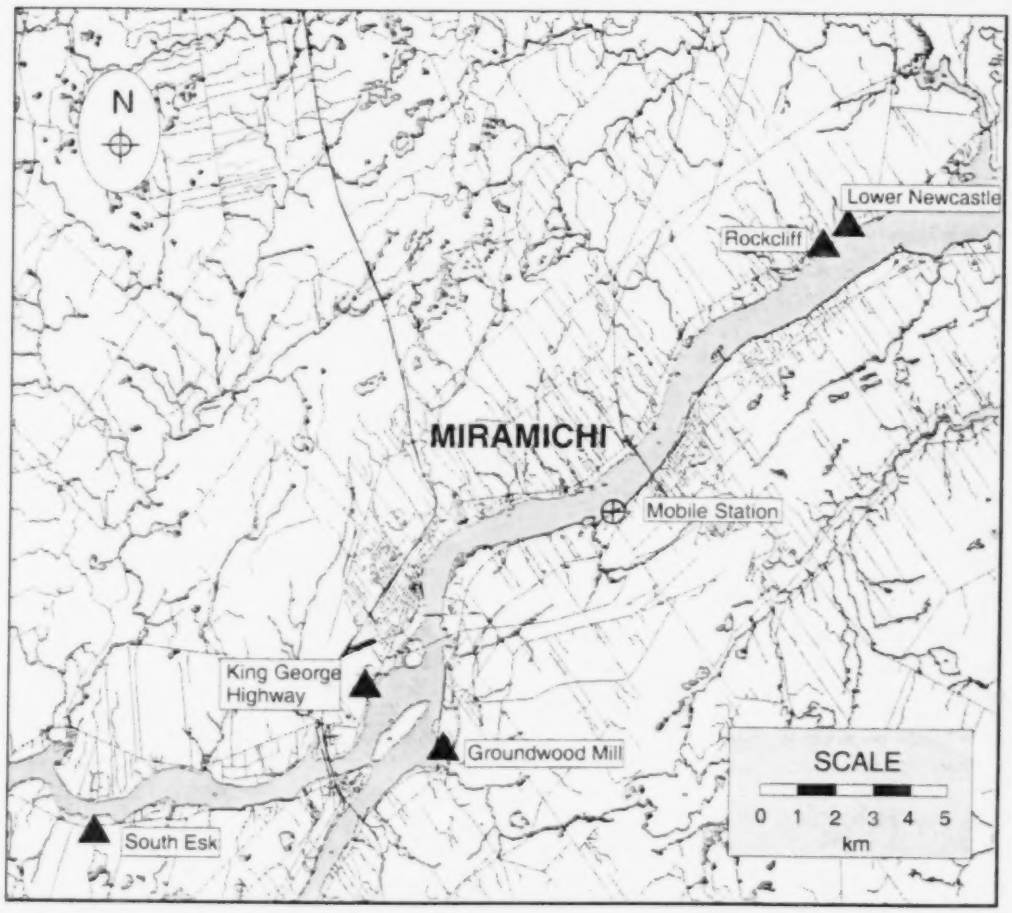


Figure 3. Air quality monitoring sites in the Miramichi Region.

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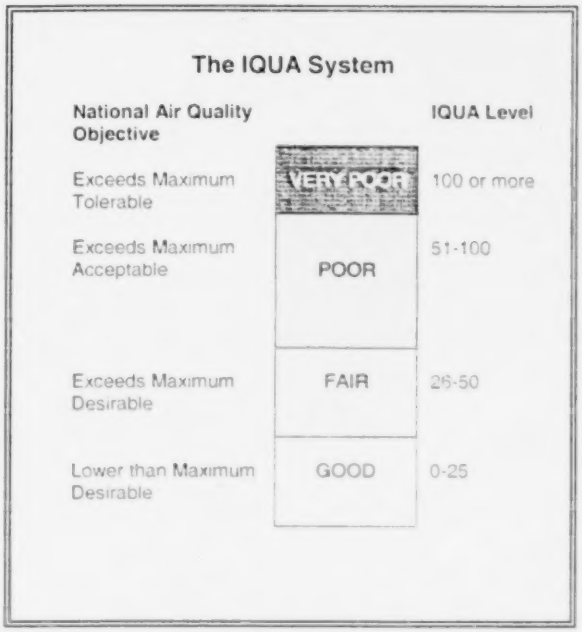

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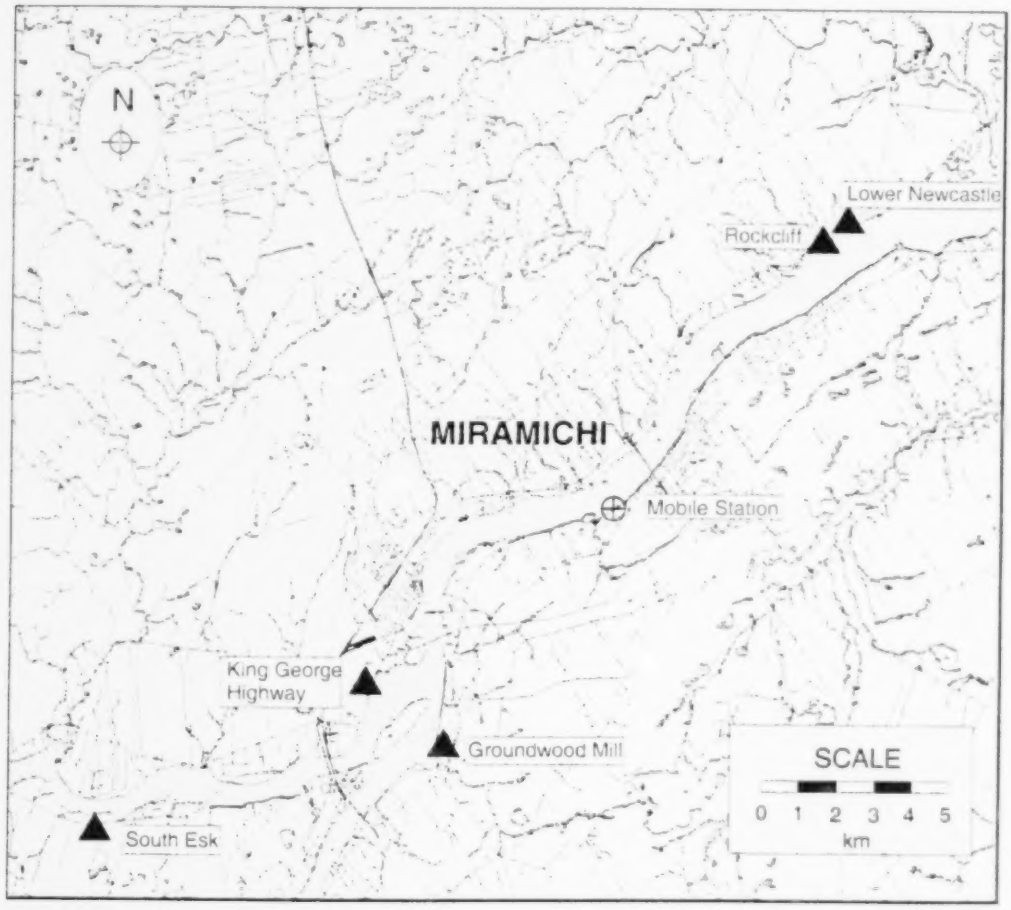

Figure 3. Air quality monitoring sites in the Miramichi Region.

B.1 UPM NETWORK

B.1.1 Hydrogen Sulphide

Based on measurements for hydrogen sulphide at the Groundwood and King George Highway sites, the compliance summary for 2001 is as follows:

Exceedances of standards for Hydrogen Sulphide in 2001
UPM sites (number of hours)

1-hour standard (11 ppb)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Groundwood	0	0	0	0	1	0	0	0	0	0	0	0	1
KG Highway	36	4	2	2	9	3	1	0	0	23	6	4	90
Total	36	4	2	2	10	3	1	0	0	23	6	4	91

24-hour standard (3.5 ppb)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Groundwood	0	0	0	0	0	0	4	0	0	0	0	0	4
KG Highway	212	37	0	5	53	77	32	26	0	136	171	23	772
Total	212	37	0	5	53	77	36	26	0	136	171	23	776

Exceedances: why they occur

Exceedances of air quality standards can occur for several reasons. For substances such as hydrogen sulphide, sulphur dioxide, nitrogen oxides, carbon monoxide and TSP, local emissions dominate. Exceedances for these contaminants may be due to emissions which are higher than usual, often together with unusual weather conditions. For example, winds blowing directly from an emission source (such as a smokestack) towards a monitoring site, or conditions when pollutants cannot disperse easily.

In the case of ozone, local emissions are far less important, and exceedances are dependent on weather patterns. Exceedances occur when winds bring ozone into New Brunswick from polluted regions beyond our borders (typically the northeastern US).

Exceedances of TSP often occur due to dust raised by the wind from roads. This often happens in April and May when surfaces dry out and roads and paths are still covered with fine sand from winter applications.

Construction of the dilute noncondensible gas collection and incineration system was completed in June 2001. The system collects odorous gases from five major point sources at the mill for incineration in No.4 Power Boiler. The conversion of the effluent treatment plant settling basins to aerated operation was completed in January 2001.

Compliance improved substantially in 2001 compared with previous years. The number of exceedances at King George Highway was over 65% lower than in 2000.

B.1.2 Total Suspended Particulate

There were no exceedances of the TSP standard at any of the three monitoring sites during 2001. Detailed results are shown in Appendix III.

B.2 MILLBANK NETWORK

The two sites at Millbank (Rockcliff and Lower Newcastle, see Figure 3) are positioned to assess the impact of NB Power's gas turbine generating station. The pollutants monitored include sulphur dioxide, nitrogen dioxide and TSP.

B.2.1 Nitrogen dioxide

There were no exceedances of the 1-hour or 24-hour standards at either monitoring site in 2001, and monthly means were all very low. Monthly results for 2001 are shown in Appendix III.

B.2.2 Sulphur dioxide

There were no exceedances of the 1-hour or 24-hour standards at either site in the network. The monthly means were also very low. This is both a reflection of the relatively infrequent operation of the Millbank plant, and the low sulphur fuel it uses. Monthly results are shown in Appendix III.

B.2.3 Total Suspended Particulate

None of the measurements made exceeded the 24-hour standard of 120 micrograms per cubic metre in 2001, and almost all were well below this value. All individual results are given in Appendix III.

B.3 Weyerhaeuser

B.3.1 Total Suspended Particulate

Weyerhauser operates a manufacturing plant for oriented strand board, located on the south shore of the Miramichi River, on the outskirts of Chatham. Two sites are maintained by this company for TSP, one at Morrison Cove and one in the Mirview Subdivision. Sampling in 2001 was on the 1 in 6 day NAPS schedule until June, and every 2 days from July-December.

During 2001, there was one exceedance of the 24-h standard of 120 micrograms per cubic metre, at the Morrison Cove site in August. The annual standard of 70 micrograms per cubic metre was not exceeded at either site. Data are summarised in detail in Appendix III.

C. Grand Lake - NB Power

Figure 4 shows the locations of the four monitoring sites in this network. These are sited to monitor the effects of the Grand Lake coal-fired electrical generating station and associated activities. The four monitoring sites are operated by NB Power and each measures sulphur dioxide and TSP.

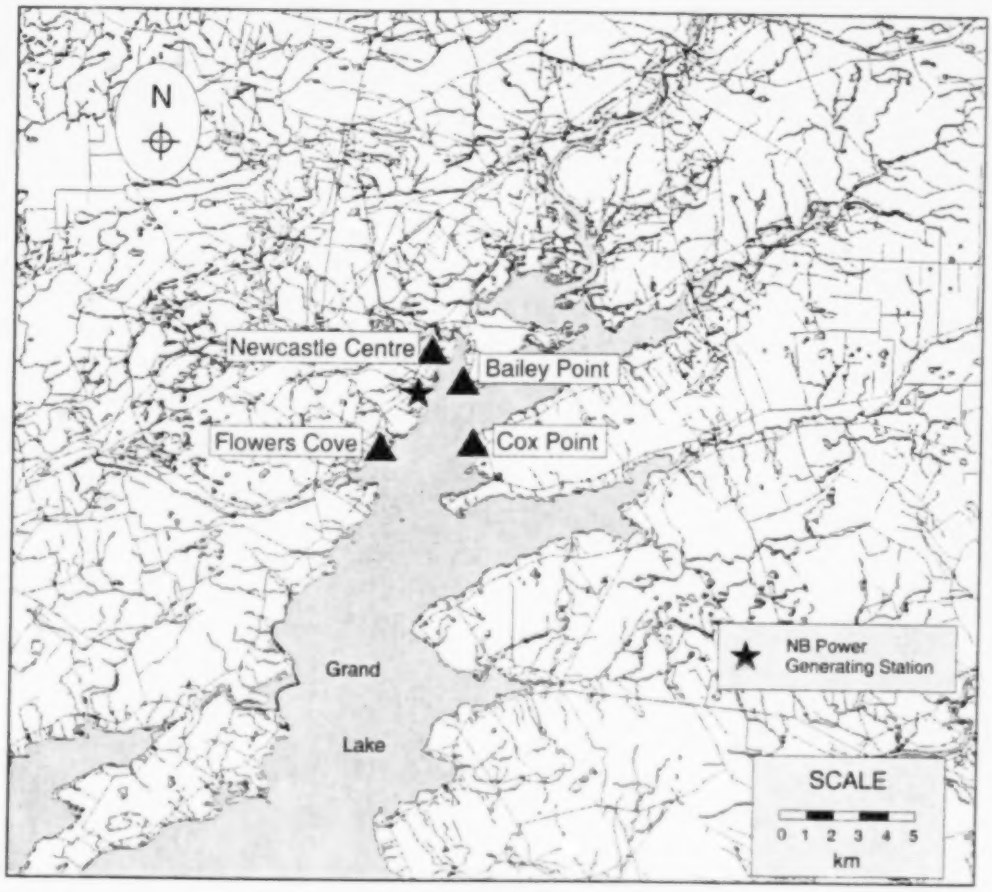

Figure 4. Air quality monitoring sites in the Grand Lake Network.

C.1 Sulphur dioxide

Compliance was good at all sites in 2001. There was a total of six exceedances of the 1-h standard of 340 parts per billion, 4 at Newcastle Centre and 2 at Cox Point. The 24-h standard of 110 ppb was not exceeded at any site.

C.2 Total Suspended Particulate

In 2001, there were no exceedances of the 24-hour standard of 120 micrograms per cubic metre in this network. Complete results are given in Appendix III.

D. EDMUNDSTON – FRASER INC.

Figure 5 shows the locations of the monitoring site (Cormier), located primarily to monitor the impacts of the Fraser Inc. pulp mill. Sulphur dioxide is monitored at this site.

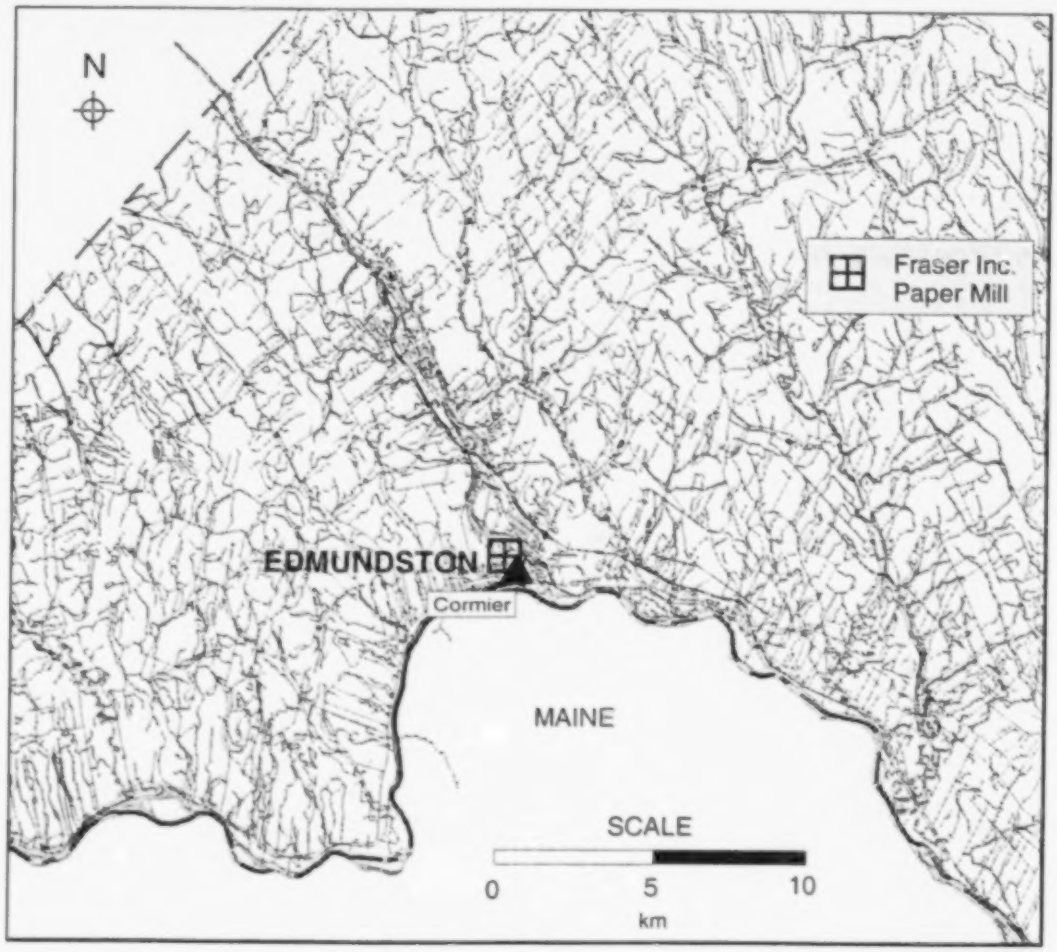

Figure 5. Air quality monitoring in Edmundston.

D.1 Sulphur Dioxide

During 2001 only the Cormier site was active. Modelling work is underway to select an alternative site to replace the Sacred Heart site, which closed in June 2000.
At the Cormier location, there were no exceedances of the 1-hour, 24-hour or annual standards during 2001.

D.2 Total Suspended Particulate

TSP was not measured in this network in 2001.

D.3 $PM_{2.5}$ Particulate Matter

Continuous fine particulate measurements began at the Cormier site in June 2000. In 2001, hourly averages rarely exceeded 60 micrograms per cubic metre. There were 30 24-hour averages exceeding the Canada-Wide Standard of 30 micrograms per cubic metre. The annual 98^{th} percentile value was 22.6 micrograms per cubic metre. Detailed results are shown in Appendix III.

E. BELLEDUNE

There are a number of monitoring sites in the Belledune region. Four of these are located for the assessment of emissions from the Brunswick Mining and Smelting complex. A further five monitors are operated for the assessment of NB Power's coal-fired electrical generating station.

Figure 6 shows the locations of all the monitoring sites in the region.

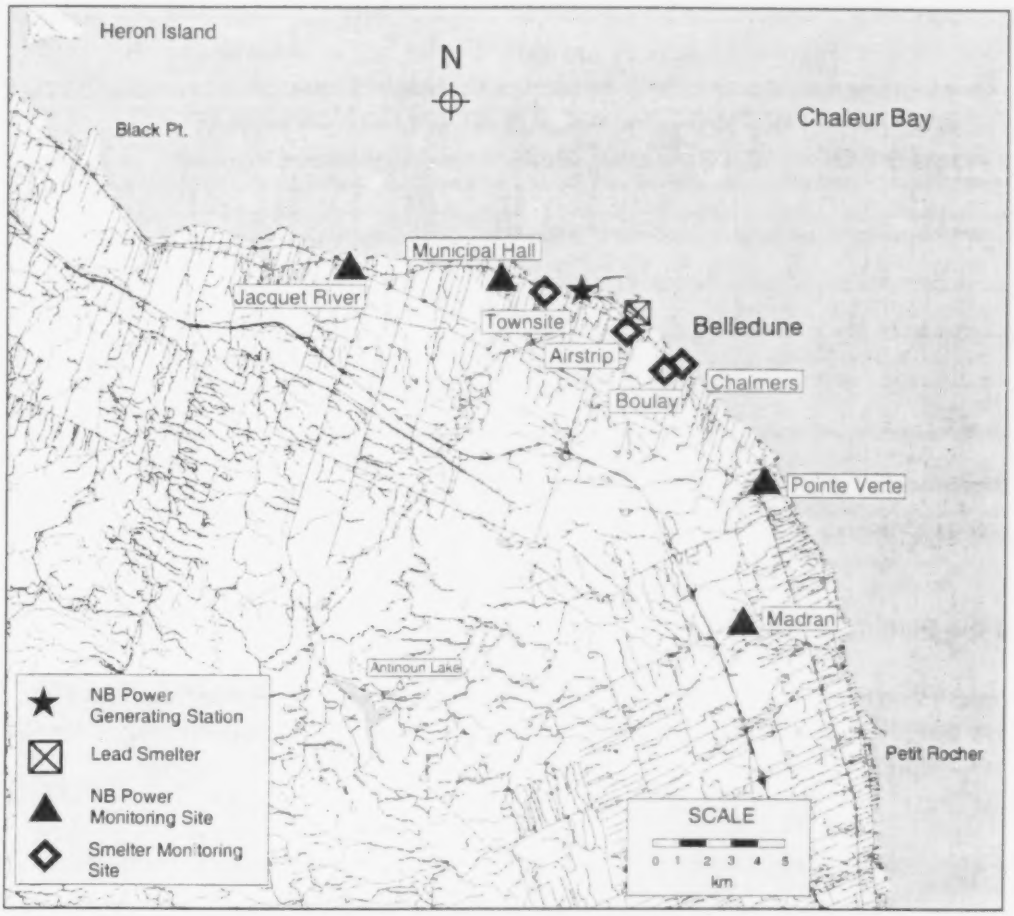

Figure 6. Air quality monitoring sites in the Belledune Network.

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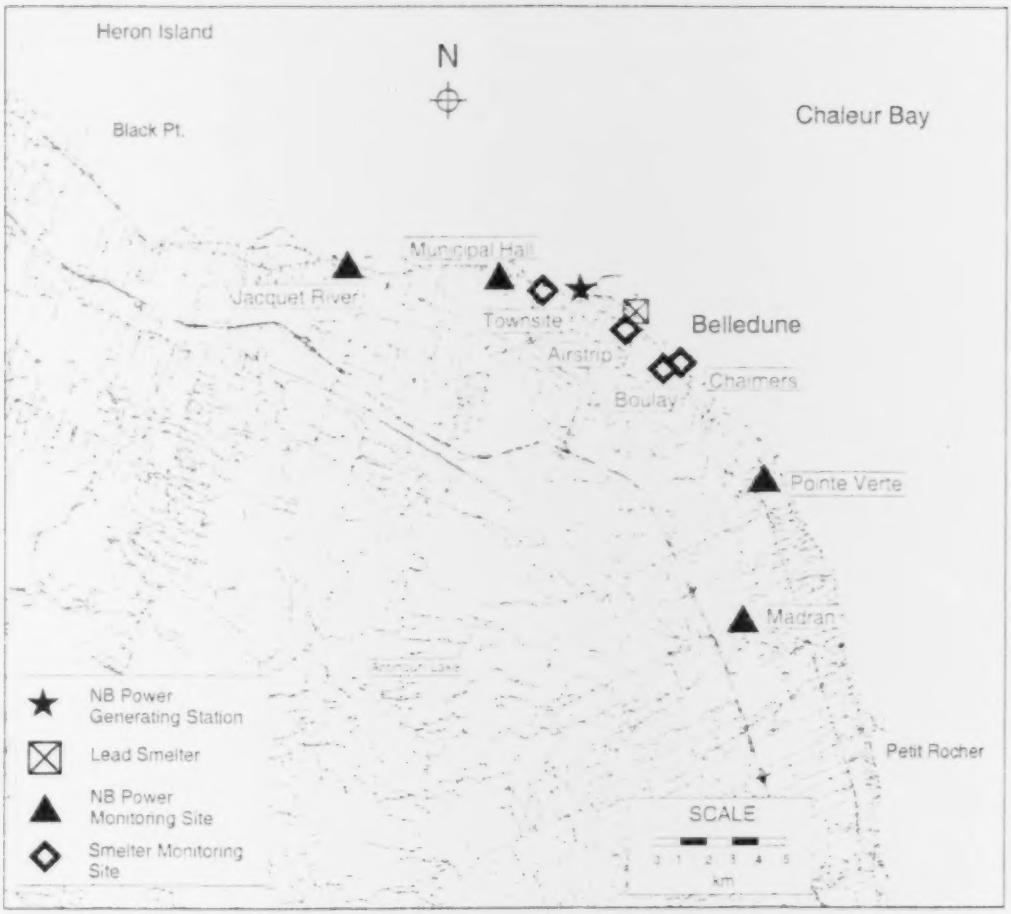

Figure 6. Air quality monitoring sites in the Belledune Network.

E.1. BRUNSWICK MINING AND SMELTING

All sites in the Brunswick Mining and Smelting network monitor sulphur dioxide, and three also measure TSP.

E.1.1 Sulphur dioxide

In 2001 there was a small number of exceedances of the 1-hour standard, as summarised below. The 1 hour standard is 34 pphm or 340 ppb.

There were no exceedances of the 24-hour standard (11.3 pphm or 113 ppb) at any station.

Exceedances of the 1-hour sulphur dioxide standard in 2001 Brunswick Mining and Smelting, Belledune (number of hours)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Airstrip	2	0	1	9	0	0	0	8	4	2	0	0	26
Chalmers	0	0	0	0	0	0	0	0	0	1	0	1	2
Townsite	0	0	0	0	0	0	0	0	0	0	0	0	0
Boulay	0	0	0	1	0	0	2	0	0	1	0	0	4
Total	2	0	1	10	0	0	2	8	4	4	0	1	32

The 1 hour standard is 34 pphm or 340 ppb.

E.1.2 Total Suspended Particulate

During 2001 there were no exceedances of the 1-h, 24-hour or annual standards at any of the three sites operating, Airfield Townsite and Boulay. Complete results are summarized in Appendix III.

E.2 NB POWER

There are five sites in this network, all of which monitor for sulphur dioxide. Two sites also monitor nitrogen dioxide.

E.2.1 Sulphur dioxide

During 2001 there were three exceedances of the 1-h standard, as summarised below.

Exceedances of the 1-hour sulphur dioxide standard in 2001
NB Power Network, Belledune (number of hours)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Madran	0	0	0	0	0	0	0	0	0	0	0	0	0
Pointe Verte	0	0	0	0	0	0	0	0	0	0	0	0	0
Belledune E	0	0	0	1	0	1	0	0	0	0	0	0	2
Jacquet River	0	0	0	0	0	0	0	0	0	0	0	0	0
Municipal Hall	0	0	0	0	0	0	0	0	1	0	0	0	1
Total	0	0	0	1	0	1	0	0	1	0	0	0	3

The 1 hour standard is 34 pphm or 340 ppb.

In 2001 there were no exceedances of the 24-hour standard of 113 ppb or annual standard of 23 ppb at any site.

E.2.2 Nitrogen dioxide

This contaminant is measured at Belledune East and Municipal Hall. There were no exceedances of the applicable 1 or 24-hour standards in 2001 at either location.

F. DALHOUSIE – NB Power

Figure 7 shows the locations of the sites in the region. The sites in this region are operated to monitor the effects of the NB Power Dalhousie electrical generating station. Six sites measure sulphur dioxide; one of the six also monitors for TSP, and there is one additional TSP site (7 sites in all). Because of potential pollution transport across the Bay of Chaleur, one of the stations is located in the province of Québec.

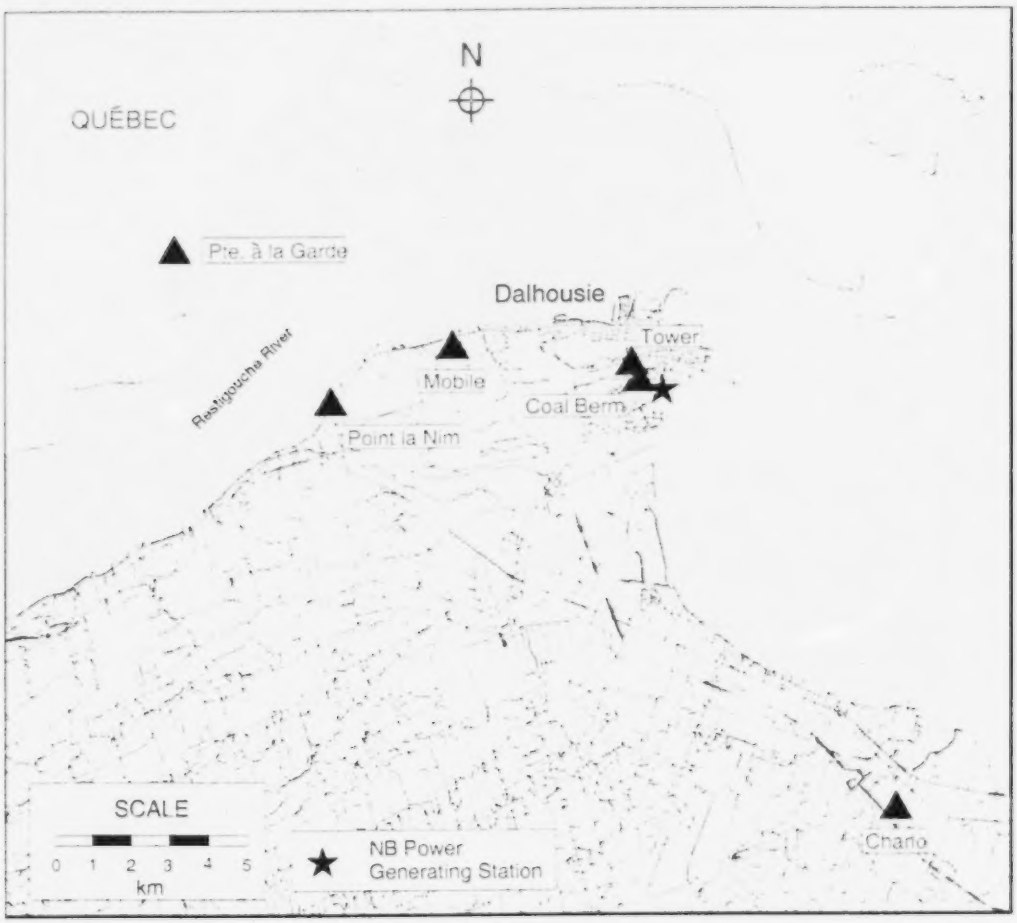

Figure 7. Air quality monitoring sites in the Dalhousie Network.

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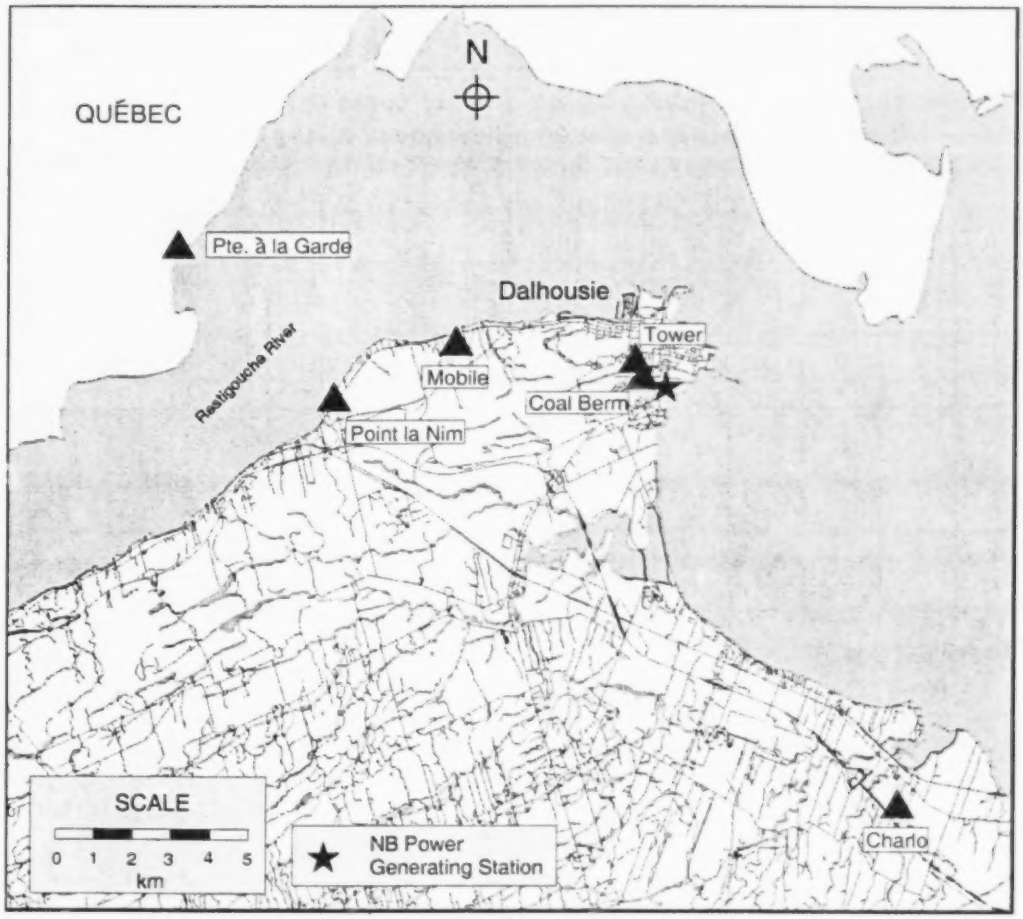


Figure 7. Air quality monitoring sites in the Dalhousie Network.

F.1 Sulphur dioxide

Compliance with the applicable 1-hour, 24-hour and annual standards was 100% at all sites in 2001, as it was in 2000. Detailed summaries are given in Appendix III.

F.2 Total Suspended Particulate

TSP was measured at the Coal Berm and Dalhousie Tower sites. Results are shown in Appendix III. None of the individual readings obtained was above the 24-hour standard of 120 micrograms per cubic metre in 2001, and the annual geometric means were also below 10 micrograms per cubic metre (the standard is 70 micrograms per cubic metre).

G. ATHOLVILLE - AV CELL INC

G.1 Sulphur dioxide

AV Cell Inc operates a pulp mill in Atholville, and maintains two associated ambient air monitoring sites, Boom Road (to the west of the mill) and Beauvista (east). Sulphur dioxide is measured at both sites. Compliance during 2001 was 100% with no exceedances of the 1-hour standard (340 ppb), 24-h standard (113 ppb) or the annual standard (23 ppb) at either site.

H. BATHURST

H.1 $PM_{2.5}$

The Bathurst monitoring station is located off St Peter Avenue, on the grounds of the Holy Family church. A TEOM monitor for $PM_{2.5}$ particulate matter is operated at this site by NBDELG. Results for 2001 showed that $PM_{2.5}$ concentrations were low in comparison to other sites, with very few hourly readings over 30 micrograms per cubic metre. The annual 98th percentile value, which will be used to determine compliance with the CWS for $PM_{2.5}$, was 12.7 micrograms per cubic metre (compared with the CWS criterion of 30 micrograms per cubic metre). There were 14 hours with a 24-h average greater than 30 micrograms per cubic metre, all of which occurred during one episode in September. A detailed summary of monthly data appears in Appendix III.

I. FREDERICTON

The Fredericton site is on Aberdeen Street, in an area representative of the "downtown" residential and business district. The site is also considered representative of a wider area for pollutants such as ozone, which are regional in nature.

I.1 Carbon monoxide

No exceedances of the 1-hour or 8-hour standards (respectively 30 ppm and 13 ppm) were recorded. Values were higher in the fall and winter months than during the summer, but even then, peak hourly readings were less than 10% of the standard.

I.2 Nitrogen dioxide

Technical problems meant that no data were recorded January-June 2001. For the remainder of the year, no exceedances of the 1 or 24-hour standards (210 ppb and 105 ppb) were recorded. As for carbon monoxide, higher readings were seen in the cooler months, but levels remained low. The highest hourly readings were about 15% of the standard.

I.3 Ground level ozone

There were no exceedances during 2001 of the national 1-hour objective for ozone. There were also no hours in exceedance of the new Canada-Wide Standard of 65 ppb (8-h average). Ozone episodes, which affected other areas in June and August, were less pronounced in Fredericton. There is additional discussion of data from the ozone network in section 11.

I.4 Total suspended particulate

Monitoring for TSP was ended at this site in January 2001.

I.5 $PM_{2.5}$ Particulate matter

Fine particulate matter ($PM_{2.5}$) was measured at the Aberdeen St site using a TEOM instrument, which provides a continuous record of particulate concentrations. Data obtained during 2001 indicated generally moderate to low particulate concentrations. There were no exceedances of the Canada-Wide Standard, a 24-hour average of 30 micrograms per cubic metre. The 98^{th} percentile value for 2001 was 18.0 micrograms per cubic metre, the same as in 2000.

I.6. Index of the Quality of the Air

Results for 2001 showed air quality in the "good" category for 99.7% of the time, with the remainder in the "fair" range. Ozone was responsible for the small number of hours in the fair range. Results were made available hourly via recorded voice message at 451 6000.

J. NACKAWIC

The St. Anne-Nackawic Pulp Company Ltd established an ambient air monitoring site during 1999, as required by the Air Quality Approval issued by the NBDELG. Sulphur dioxide, total reduced sulphur (TRS) and total suspended particulate (TSP) are measured, as well as wind speed and direction.

Compliance was 100% for sulphur dioxide and TRS during 2001. The results for TSP also showed low concentrations and no exceedances were recorded.

K. MONCTON

The Moncton air quality monitoring site is situated at the Highfield Street water pumping station. The site location was chosen to provide readings representative of the central city suburbs, in areas which may be influenced by emissions from vehicles or institutional heating systems, as well as regional pollutants such as ozone.

K.1 Carbon monoxide

No exceedances of hourly or 8-hourly standards for carbon monoxide occurred during 2001. Readings were similar to those recorded in downtown Saint John, and although slightly higher than those in Fredericton, were still well below standards.

K.2 Nitrogen dioxide

No exceedances of hourly or 24-hourly standards for nitrogen dioxide were recorded during 2001. Maximum hourly values were less than 20% of the standard.

K.3 Ozone

There were 3 exceedances of the hourly objective for ozone (82 ppb) and 24 exceedances of the Canada-Wide Standard (65 ppb over 8 hours). More discussion of ozone data may be found in section 11.

K.4 $PM_{2.5}$ Particulate matter

The 2001 results revealed low concentrations, with few hourly values over 30 micrograms per cubic metre ($\mu g/m^3$). The Canada-Wide standard of 30 $\mu g/m^3$ was exceeded on 6 hours, during an episode in October. The 98th percentile value for the year was 17.2 $\mu g/m^3$, compared to the CWS criterion of 30 $\mu g/m^3$.

K.5 Index of the Quality of the Air

Hourly IQUA reports are generated for the Moncton site and made available via recorded message at 851 6610. Summary statistics for 2001 indicated that good air quality was recorded for 97.1% of all hours in 2001, and fair for the remainder. The fair readings were due to ozone.

L. ST. ANDREWS

The St. Andrews monitoring station is located on the grounds of the Huntsman Marine Science Centre and is operated with the support of staff from the Centre and NBDELG. This site has been used for a variety of special sampling projects and is especially suitable for investigating trans-boundary air pollution. Currently, projects operated at St Andrews by the province include ozone and $PM_{2.5}$ monitoring. Additionally, mercury concentrations in air and precipitation are monitored at this site, in collaboration with Environment Canada. This is the only location in the province where these kind of measurements are made, and one of only two in the Maritimes.

L.1 $PM_{2.5}$ (TEOM)

The St Andrews TEOM unit collected valid data for over 99% of the year during 2001. In general, readings were very low at this site, hourly values seldom exceeded 30 micrograms per cubic metre, with the majority below 15 micrograms per cubic metre. The new Canada-Wide Standard of 30 micrograms per cubic metre (24-h average) was not exceeded at any time during the year. The 98th percentile value for the year (based on 24-hour averages) was 19.6 micrograms per cubic metre.

L.2 Mercury monitoring

Mercury is of concern as an environmental contaminant because of its ability to accumulate in living organisms, potentially reaching concentrations which could pose a hazard to health in humans and wildlife (e.g. NESCAUM, 1998). Although mercury has been recognised as an environmental pollutant for decades, relatively little monitoring and assessment of the transport and behaviour of mercury in the atmosphere has taken place. Most attention has been paid to direct discharges, for example of industrial, water-borne effluents. In 1998, the New England Governors and Eastern Canadian Premiers identified mercury as a substance of concern in the east of Canada and the United States, and developed an Action Plan to improve our understanding of its impacts, as well as proposing measures to reduce man-made emissions (NEGECP, 1998).

Mercury monitoring conducted at St Andrews contributes to the scientific understanding of mercury in the environment. The results are used in research (for example into atmospheric processes) as well as in wildlife and other studies.

The following table summarises results of the mercury monitoring program so far. These monitoring studies are operated cooperatively between Environment Canada, the Huntsman Marine Science Centre, and NBDELG.

Mercury Monitoring Results 1995-2001

Ambient Air

St Andrews		Other sites	
Year	Annual Average (ng/cubic metre)	Site	Annual averages (ng/cubic metre)
1995	1.9	Mt Mansfield, VT	2.0 (94-96)*
1996	1.5	Kejimkujik, NS	1.5 (1996)*
1997	1.4	Westfield, NY	2.6 (94-96)*
1998	1.4	Moss Lake, NY	2.4 (94-96)*
1999	1.6		
2000	1.4		
2001	1.4		

Precipitation (rain and snow)

Year	Mean mercury concentration (ng/L)	Kejimkujik, N.S.	Mean mercury concentration (ng/L)
1996	7.5**	1996	7.4**
1997	6.7**	1997	5.9**
1998	5.8**	1998	5.2**
1999	6.5**	1999	5.0**
2000	6.5**	2000	4.7**
2001	6.3**	2001	5.4**

Notes:
ng = nanograms. 1 nanogram is one thousand-millionth of a gram. Ambient air mercury data supplied by Environment Canada.

References:

* NESCAUM (1998)
** NADP (2000)

There are no environmental guidelines or objectives for mercury in air or precipitation at present. The data may be used to look for patterns or trends over time, and to compare regionally with other locations. They are also used as input to ecological models which attempt to track how mercury moves though different components of the environment.

The results show several things. In ambient air, the concentration of mercury in vapour form varied between approximately 1.5 and 2 nanograms per cubic metre as an annual average. These values are similar to those measured in Nova Scotia and rural southern Quebec, and lower than readings obtained at sites in parts of New England or southern Ontario, which typically range from 2 to 3 nanograms per cubic metre (NESCAUM, 1998). Over the course of a year, readings at St. Andrews tend to be highest in late winter and lowest in late summer. The reasons for this have not yet been fully explored, but the changing use of fossil fuels through the year is thought to be a major influence (NESCAUM, 1998).

Considering mercury measurements in precipitation, the trends seen at St. Andrews and at Kejimkujik in southwestern Nova Scotia, are similar. Mercury concentrations have generally fallen at both sites since 1996. However at St Andrews, there was an increase from 1998 to 1999 (sustained in 2000, with a similar result in 2001) and results from St. Andrews are consistently higher than those from the Nova Scotia location. A detailed examination of results shows that the two sites occasionally exhibit significant differences in mercury concentrations for the same precipitation episodes.

11. RURAL OZONE NETWORK - SOUTHERN NEW BRUNSWICK

Figure 8 shows the locations of the sites which monitor ground level ozone in New Brunswick. This network is operated to assess the impact of long-range transported ozone. It focuses on the southern portion of the province, which is the region most affected by long range transport, as shown by special short-term monitoring studies and trajectory analyses (e.g. Fuentes and Dann, 1994; Tordon et al., 1994; Multistakeholder NOx/VOC Science Program, 1997a, 1997b). Two sites in the northern part of the province were added to the network in 2000, St Leonard in the northwest, and Lower Newcastle in the northeast.

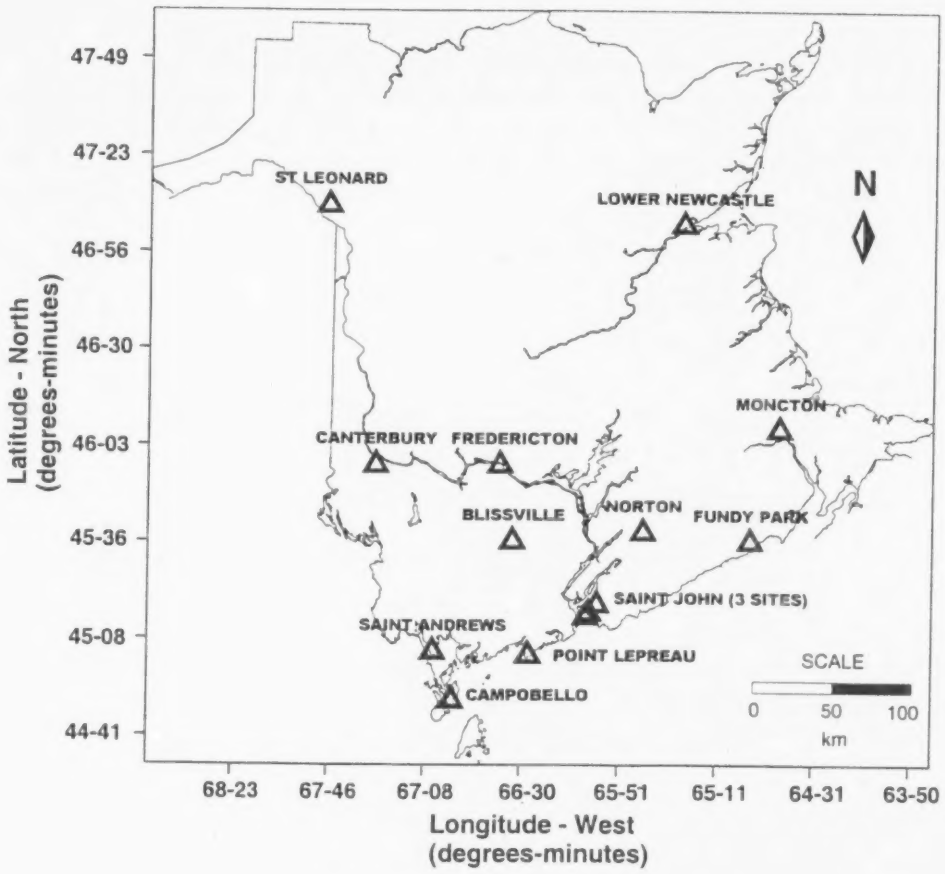


Figure 8. Locations of ozone monitoring sites in New Brunswick (2001).

Ground-level ozone readings in 2001 were higher than in 2000. There were a number of exceedances of the 1-h objective of 82 ppb, mostly in the south east from June to September. The number of hours of exceedance is quite variable from year to year, being heavily influenced by the weather. Considering the Canada-Wide Standard of 65 ppb averaged over 8 hours, there was a total of more than 400 exceedances in the provincial network, occurring at 10 sites and distributed from May to October. Exceedances are summarised in the following tables.

Exceedances of the 1-hour ozone objective, 2001 (number of hours)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Customs	0	0	0	0	0	0	0	2	0	0	0	0	2
Forest Hills	0	0	0	0	0	0	0	0	0	0	0	0	0
Hillcrest	0	0	0	0	0	0	0	4	0	0	0	0	4
Canterbury	0	0	0	0	0	0	0	0	0	0	0	0	0
Pt. Lepreau	0	0	0	0	0	0	0	0	0	0	0	0	0
St Leonard	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower Newcastle	0	0	0	0	0	0	0	0	0	0	0	0	0
St. Andrews	0	0	0	0	0	0	0	0	0	0	0	0	0
Campobello Isl.	-	-	-	0	0	0	0	1	0	-	-	-	1
Fundy Park	0	0	0	0	0	4	0	1	1	0	0	0	6
Norton	0	0	0	0	0	0	0	3	0	0	0	0	3
Moncton	0	0	0	0	0	3	0	0	0	0	0	0	3
Fredericton	0	0	0	0	0	0	0	0	0	0	0	0	0
Blissville	0	0	0	0	0	10	0	0	0	0	0	0	10
Total	0	0	0	0	0	17	0	11	1	0	0	0	29

The 1 hour National Objective is 82 ppb. The Campobello site is operated in summer only.

Exceedances of the 8-hour Canada Wide Standard for ozone, 2001 (number of hours)													
Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Customs	0	0	0	0	0	3	0	10	0	0	0	0	13
Forest Hills	0	0	0	0	0	0	0	0	0	0	0	0	0
Hillcrest	0	0	0	0	0	10	8	38	20	14	0	0	90
Canterbury	0	0	0	0	0	0	0	0	0	0	0	0	0
Pt. Lepreau	0	0	0	0	0	11	5	20	0	0	0	0	36
Lower Newcastle	0	0	0	0	0	0	0	0	0	0	0	0	0
St Leonard	0	0	0	0	7	0	0	5	0	0	0	0	12
St. Andrews	0	0	0	0	0	13	1	6	0	0	0	0	20
Campobello Isl.	0	0	0	0	0	9	5	12	0	0	0	0	26
Fundy Park	0	0	0	0	0	14	8	21	22	7	0	0	72
Norton	0	0	0	0	0	17	8	15	6	7	0	0	53
Moncton	0	0	0	0	0	14	5	0	0	5	0	0	24
Fredericton	0	0	0	0	0	0	0	0	0	0	0	0	0
Blissville	0	0	0	0	0	28	5	19	14	0	0	0	66
Total	0	0	0	0	7	119	45	146	62	33	0	0	412

The Canada Wide Standard is 65 ppb averaged over 8 hours.

The frequency of ozone episodes (periods of one or more days with high readings) in New Brunswick is dependent on summer weather conditions. Ozone events typically occur when weather systems result in transport of air into the province from the south-west. A greater than normal frequency of west to north-westerly winds results in fewer days with high ozone.

Monthly means and extremes are shown in Appendix III. There is a natural seasonal cycle in ozone levels, with higher values being seen in the spring months. This is due to seasonal patterns in atmospheric circulation. This feature is apparent at most New Brunswick sites. Monthly mean values can be seen to peak in March and April.

12. ACID PRECIPITATION NETWORK

New Brunswick has operated an extensive precipitation chemistry network since the early 1980s. Since 1987, this has been a partnership effort, with logistical and financial support from NB Power. All samples are analysed at the NBDELG laboratory, and DELG staff co-ordinate the monitoring program, perform data quality assurance, and maintain the official data archive.

The potentially adverse impacts of acid precipitation have been recognised for more than 20 years. Acid rain effects are felt regionally, not just close to the sources of contaminants themselves. The emissions which cause acid precipitation (primarily sulphur and nitrogen oxides) typically travel long distances - hundreds or even thousands of kilometres - before returning to the surface in rain or snow. The same emissions also contribute to regional haze and fine particulate pollution.

Precipitation chemistry in New Brunswick is affected by the emissions from several large industrial regions which lie upwind, including the American midwest, southern Ontario and Québec, and the Washington-Boston region.

Partly because the site of impact is remote from the point of emission, no standards have been put in place for acid precipitation. Instead, the issue has been managed by the adoption of 'target' or 'critical' loads. These are similar to the objectives used in the management of other air pollutants. Although they are not legally enforceable, they do provide a goal towards which affected US States and Canadian Provinces are working, as emissions are reduced over time.

The severity of acid rain impact is generally measured by computing how much sulphate (a measure of sulphuric acid) falls on each hectare over one year. The target load for acid rain is expressed in terms of this amount of sulphate. In the late 1980s, the proposed target load for eastern Canada was 20 kilograms per hectare per year (kg/ha/yr).

This target was initially designed to provide protection to areas which are moderately sensitive to acidification. This sensitivity varies in different areas, because geological characteristics such as soils and bedrock have different abilities to neutralise the acid precipitation. This is often referred to as the 'buffering capacity'.

Over time, scientists realised that these initial target loads were not adequate to provide long term protection, or protect more sensitive watersheds. The newer concept of critical loads was introduced in the 1990s. Critical loads take into account the nature of individual watersheds, and are calculated to ensure long-term protection from acidification.

Critical loads for acidification in New Brunswick range from less than 8 up to 11 kg/ha/year of sulphate input (referred to as acid sulphate deposition). The lowest values of less than 8 kg/ha/yr refer to the most sensitive areas on granite bedrock (e.g. areas of southwestern and central northern New Brunswick), and 11 kg/ha/yr to most of the rest of the Province.

In recent years, acidic deposition has been declining slowly. This means that the critical load values are beginning to be met over some parts of the Province, although still exceeded in others, notably the sensitive regions in the southwest. There is, however, still more effort required to reduce acid deposition further and ensure that the more sensitive lakes and rivers, such as those in southwestern N.B., are provided with long term protection from acid damage. Further cuts in sulphur dioxide emissions are being pursued, both in the Province and those regions of eastern Canada and the United States which are the main source regions of these acid-causing emissions.

Figure 9 shows the location of monitoring sites, and Figure 10 the acid deposition recorded in 2001. Acid deposition values in 2001 were the lowest seen in the province since organised monitoring began. This was primarily due to below normal precipitation: all areas of the province experienced deficits, which ranged from 200 mm below normal in the northwest, to over 600 mm below normal in the Saint John area. In percentage terms, these deficits equate to 30 to 40% below normal. In line with the precipitation pattern, the largest reductions in acid deposition in 2001 were in southern New Brunswick, with Fundy Park having an annual deposition total 44% lower than in 2000.

Acid deposition, the total amount of a chemical substance entering the environment, is a factor of both concentration in the precipitation and the amount of precipitation received. As a result, there will always be significant variability in acid deposition between years due to variability in weather patterns. Results presented in the following section on long terms trends indicate that when averaged across the province, the concentration of acidic pollutants in precipitation (which is less dependent of the amount of precipitation received) appears to be falling. Although encouraging, the data also show that the acid rain issue remains important in New Brunswick, as critical loads for acid rain continue to be exceeded, especially in the south. This remained true in 2001: although deposition values were the lowest recorded, critical loads were still exceeded in most areas.

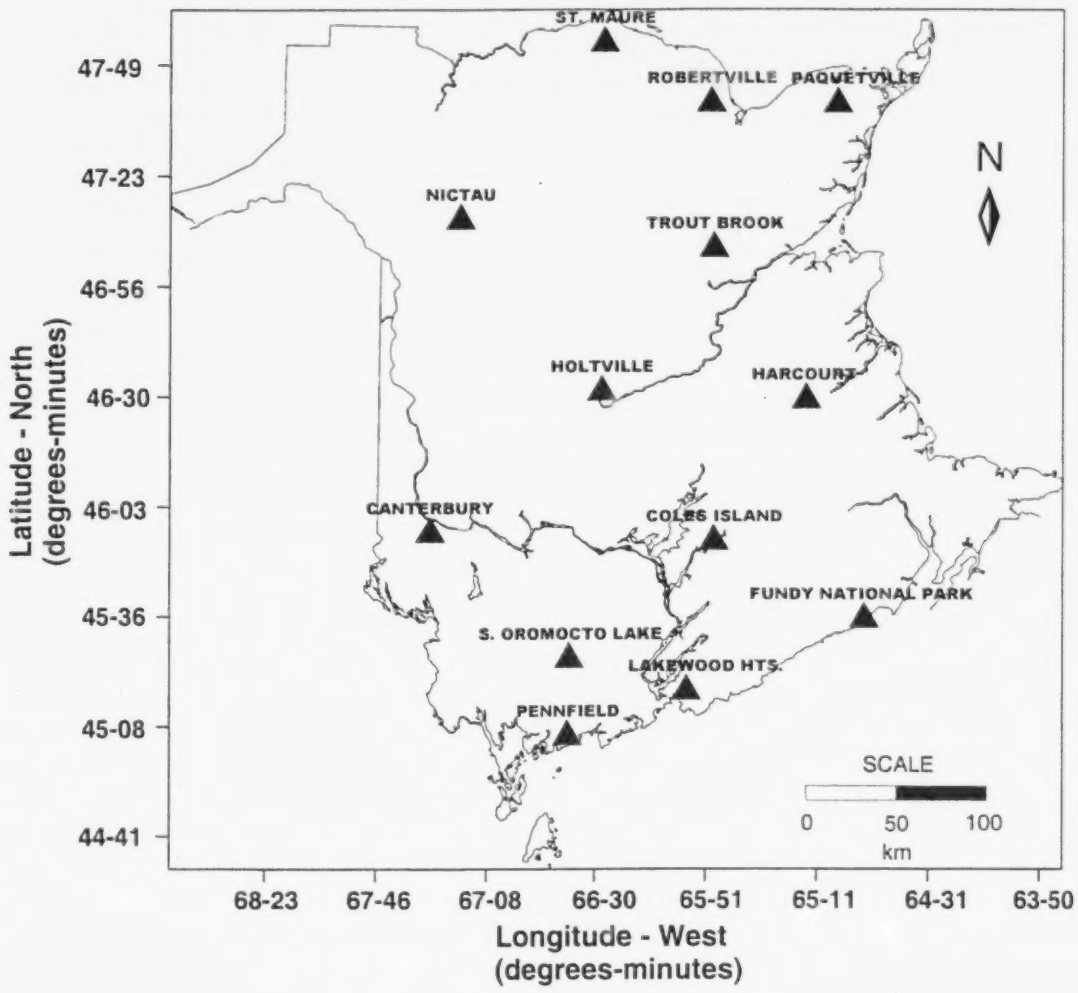


Figure 9. Location of acid rain monitoring sites in New Brunswick (2001).

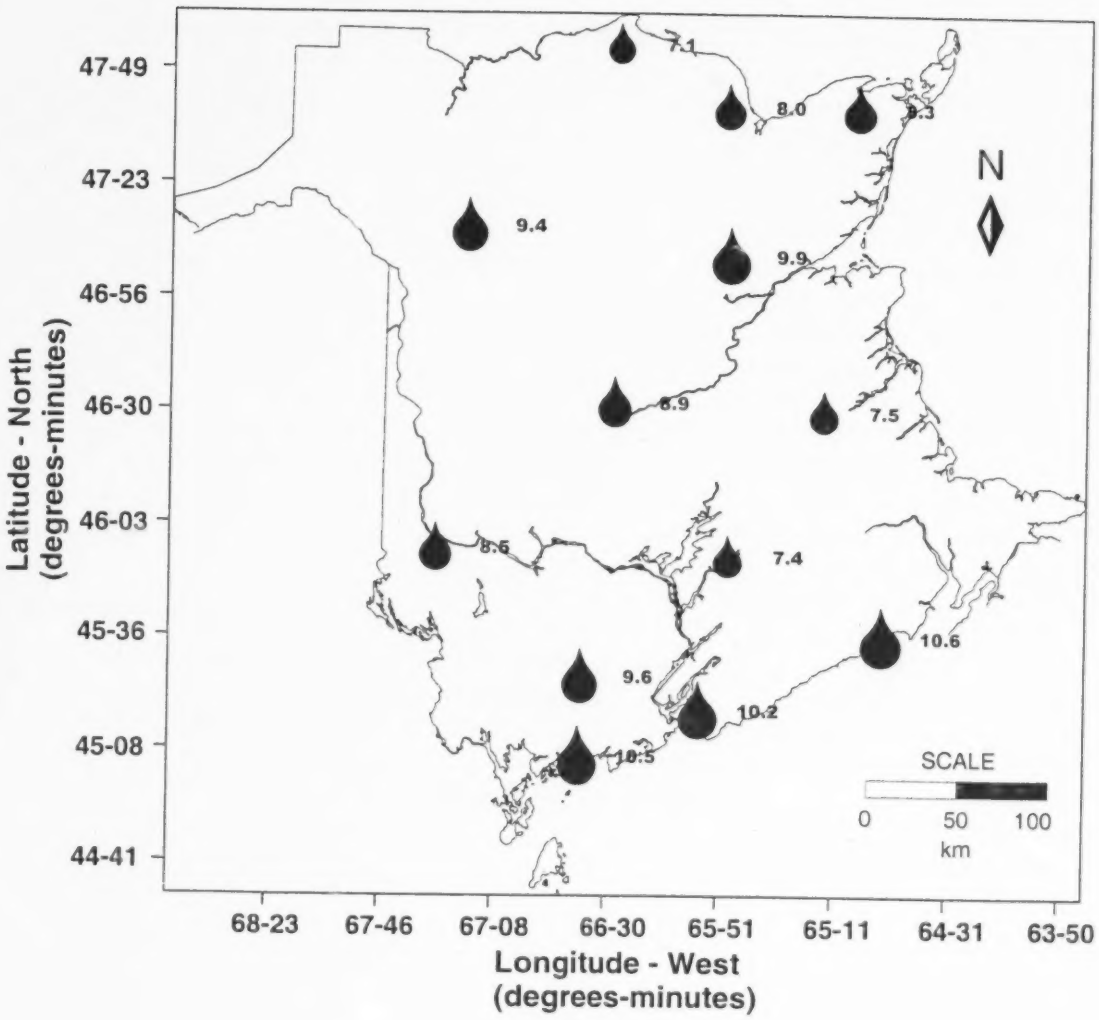


Figure 10. Acid deposition for 2001 (kilograms per hectare per year of sulphate).

The droplet symbols are sized in proportion to the deposition measured at that site.

A. New England Governors/Eastern Canadian Premiers Acid Rain Action Plan

Since the early 1980s the New England Governors/Eastern Canadian Premiers (NEGECP) have met annually to discuss items of regional interest, such as trade, tourism and the environment. In the 1980s and early 1990s this collaboration led to significant efforts to address the acid rain issue, and develop emission control programs.

The NEGECP held their 2001 annual meeting, in August in Westbrook, Connecticut. Progress in 2001 included the publication of a document entitled "Data Without Borders," which presented the status of NEGECP work on the acid rain issue, containing details of work on data exchange, ozone and fine particulate mapping and forest mapping for critical loads. An Acid Rain Communications Plan was also completed, building on the results of the survey of public opinion conducted in 2000. The Communications Plan outlines a number of proposed actions, including the development of school curriculum materials, speakers kits, radio adverts, internet material, factsheets and brochures, and organising a conference on air quality and health. A report was also produced detailing the status of implementing the NEGECP Mercury Action Plan.

The NEGECP also produced a report entitled "Climate Change Action Plan 2001", presenting its plans for addressing the climate change issue on a number of fronts, including among others an emissions inventory, public awareness, the electrical generation sector, and energy conservation.

Full details of these reports are available via the NEGECP web site, at:

http://www.cmp.ca/en-main1.html.

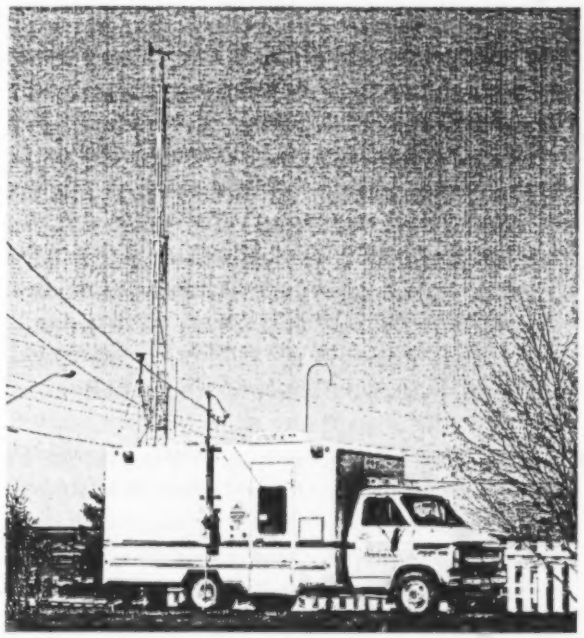
B. Canada-Wide Acid Rain Strategy for Post-2000

In October 1998, this strategy was signed by the Ministers of Environment and Energy of all provinces and territories. The Post-2000 Strategy updates efforts which have been going on since the mid 1980s to reduce emissions which contribute to acid rain. Efforts from 1985 to date have reduced sulphur dioxide emissions in eastern Canada by 50% from 1980 levels. The Post-2000 strategy contains plans to reduce acid-causing emissions even further, recognising that although progress has been made, more reductions are still needed to enable critical loads to be reached. The strategy also provides direction for other activities such as scientific monitoring and research, and t makes a formal commitment to seek further reductions in sulphur dioxide emissions from the United States. The Strategy addresses pollution prevention, specifically "keeping clean areas clean", aims to ensure the adequacy of acid rain science and monitoring programs, and reports on SO_2 and NOx emissions and forecasts.

During 2001, all provincial emissions targets were finalized, with the December 2001 announcement by Nova Scotia of its energy strategy. Following the declaration of the emissions reduction targets, work began on drafting bilateral agreements between the federal government and the eastern provinces, to formalize the targets. The Canada-US Air Quality Committee examined the issue of particulate matter, expected to lead to a new Annex to the Canada-US agreement in 2004.

Additional deposition modelling was carried out, using the Acid Deposition and Oxidants (ADOM) model to examine the effect of a variety of new emission reduction scenarios.

13. MOBILE AIR QUALITY MONITORING UNIT



To help in evaluating air quality in New Brunswick, the Department of the Environment and Local Government has developed a mobile air quality monitoring unit. It augments monitoring carried out at established monitoring sites and can be moved to most areas of the province, fulfilling temporary monitoring needs.

The vehicle is presently able to measure the following pollutants: sulphur dioxide, nitrogen oxides, total reduced sulphur (including hydrogen sulphide) and fine particulate matter (PM_{10} or $PM_{2.5}$). The vehicle is also fitted with a retractable 10 metre mast with wind speed and direction instruments. Additional monitoring capabilities may be added in the future, for example for VOCs.

The mobile air monitoring vehicle will be used in the following applications:

- Assessment of the local impact of point or area emission sources
- An evaluation tool in responding to local air quality issues
- Site evaluation prior to establishing a permanent monitoring site
- Comparative analysis studies with permanent monitoring sites
- Validation of predictive air quality modelling studies
- Determination of background or baseline air quality
- Investigating a planned or sustained event that has potential for air quality impacts, e.g. slash burning, forest fire, fire training exercise.

The mobile unit was initially set up in east Saint John, in an area of the Grandview Industrial Park, to investigate air quality in a region to the south of the oil refinery, following major changes to the refinery. The unit operated here from February to May 2001.

From June to October 2001, the mobile monitoring unit was operated in the Miramichi region, to investigate air quality downwind of the Weyerhaeuser wood products facility.

Finally in November and December, the unit was relocated back to east Saint John to continue monitoring at the same location used earlier in the year.

Monitoring results are summarized in the following tables.

Mobile Monitoring Unit – Data Summary 2001 Saint John, Grandview Industrial Park						
	Feb	Mar	Apr	May	Nov	Dec
SO_2						
Coverage (%)	28	90	88	10	21	64
1-h exceedances (>170 ppb)	0	15	29	0	0	0
24-h exceedances (>60 ppb)	0	54	93	0	0	0
TRS						
Coverage (%)	-	-	-	-	22	63
1-h exceedances (>11 ppb)	-	-	-	-	0	0
24-h exceedances (>3.5 ppb)	-	-	-	-	0	0
NO_2						
Coverage (%)	-	-	-	-	21	66
1-h exceedances (>210 ppb)	-	-	-	-	0	0
24-h exceedances (>105 ppb)	-	-	-	-	0	0
$PM_{2.5}$						
Coverage (%)	22	92	97	11	22	66
$PM_{2.5}$ Max 24-h average	6.3	12.0	12.0	23.5	32.6	8.6
$PM_{2.5}$ Mean	3.6	5.0	5.4	12.9	16.0	4.1

Mobile Monitoring Unit – Data Summary 2001 Miramichi, Morrison Cove					
	Jun	Jul	Aug	Sep	Oct
SO_2					
Coverage (%)	39	95	96	95	69
1-h exceedances (>170 ppb)	0	0	0	0	0
24-h exceedances (>60 ppb)	0	0	0	0	0
TRS					
Coverage (%)	41	100	100	100	72
1-h exceedances (>11 ppb)	0	0	0	0	0
24-h exceedances (>3.5 ppb)	0	0	0	0	0
NO_2					
Coverage (%)	41	99	100	100	72
1-h exceedances (>210 ppb)	0	0	0	0	0
24-h exceedances (>105 ppb)	0	0	0	0	0
$PM_{2.5}$ (Jun-Aug) PM_{10} (Sep-Oct)				PM_{10}	PM_{10}
Coverage (%)	41	99	100	78	72
Max 24-h average	15.9	18.3	27.7	38.6	26.4
Mean	7.2	6.2	6.3	12.7	12.4

Note: "coverage" means the percentage of the hours in each month for which valid data were obtained. All results in ppb except $PM_{2.5}$ and PM_{10}, which are in micrograms per cubic metre.

A. Saint John - Grandview Industrial Park

$PM_{2.5}$ results were low. There was one day in November when the Canada-Wide Standard for $PM_{2.5}$ of 30 micrograms per cubic metre was exceeded. Sulphur dioxide results included 44 exceedances of the 1-hour standard and 147 of the 24-h standard, occurring in March and April. Peak SO_2 readings were higher than at any of the permanent sites in the Saint John monitoring network, twice reaching 500 ppb in March. This indicated a need to further assess pollutant impacts at this location. The mobile unit was returned to the same site for November and December 2001, but SO_2 concentrations did not exceed 118 ppb during those months. Further assessments in this location are planned. TRS and NO_2 monitoring was conducted in November and December, and very low readings were obtained, with no exceedances.

B. Miramichi – Morrison Cove

Results from June to October 2001 at this location showed low levels for SO_2, NO_2 and TRS, with no exceedances being recorded. $PM_{2.5}$ concentrations were similar to those recorded in Saint John (Grandview Avenue), and were generally moderate or low.

In September, particulate monitoring switched to PM_{10}, to further investigate particulate impacts at this site. Results showed that concentrations were generally higher in this size range than $PM_{2.5}$. However, peak hourly values seldom exceeded 50 micrograms per cubic metre, and 24-hour concentrations did not exceed 40 micrograms per cubic metre.

14. LONG TERM AIR POLLUTION TRENDS

In addition to examining air quality monitoring results for a given year, it is often informative and revealing to compare annual results to previous years, and consider longer term trends. This provides information on how air quality may be changing over the years, and whether emission control measures as applied to industrial operations and consumer products (notably vehicles) are influencing long term environmental quality. As mentioned in the introduction, air quality monitoring has been ongoing in parts of the province since the 1970s, especially in the Saint John region. In this section, data for key locations with long-term records are presented to provide information on air quality trends.

A. Carbon Monoxide

The only long term site for this substance is the Customs Building site in uptown Saint John. The earlier part of the record (prior to 1991) is from the nearby Post Office location. Results are predominantly influenced by motor vehicle emissions. Results show that since 1980, the annual average has changed relatively little. There are signs of a possible decrease from 1980 to the mid 1990s, and an increase since then, although the variability between years reduces the confidence that these are meaningful

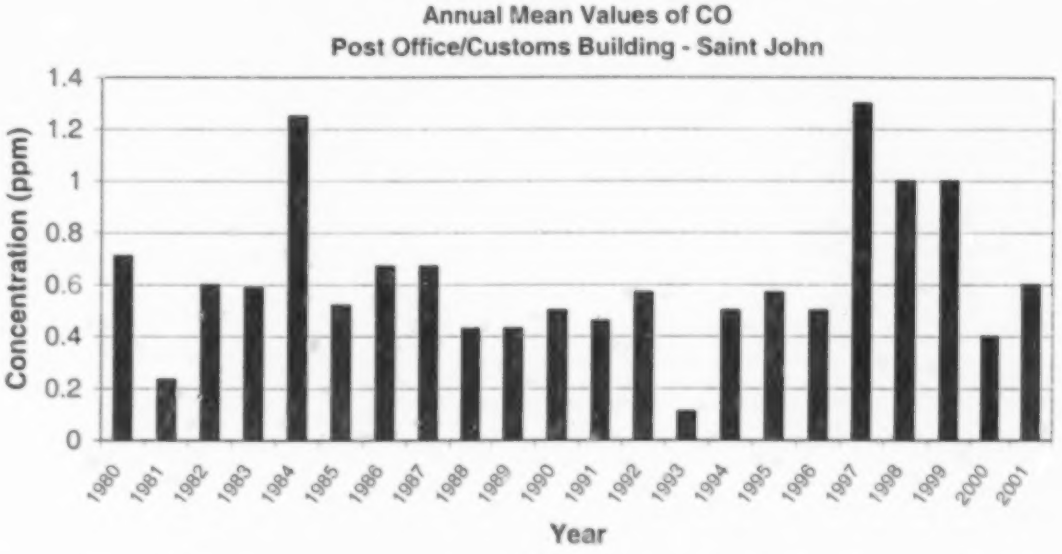


Figure 11. Annual mean values of carbon monoxide, Post Office/Customs Building, Saint John, 1980-2001.

patterns. During the period in question the population of Saint John has increased approximately 4% (Aldighieri, 1998). The number of vehicles registered and more notably, the average total kilometres driven each year, have been increasing throughout the 1990s (Goggin, 1999; Transport Canada, 1999; Statistics Canada, 1999). These pressures, which tend to increase carbon monoxide emissions, have been offset by a greater proportion of vehicles fitted with emissions control equipment, such as catalytic converters.

B. Nitrogen dioxide

Forest Hills

Nitrogen dioxide is another key pollutant emitted by motor vehicles, as well as industrial sources. The trend at Forest Hills, in suburban east Saint John, appears to be downward since 1981, with little variation between years since 1988. Forest Hills is influenced by emissions from local industries as well as the more diffuse sources such as vehicles.

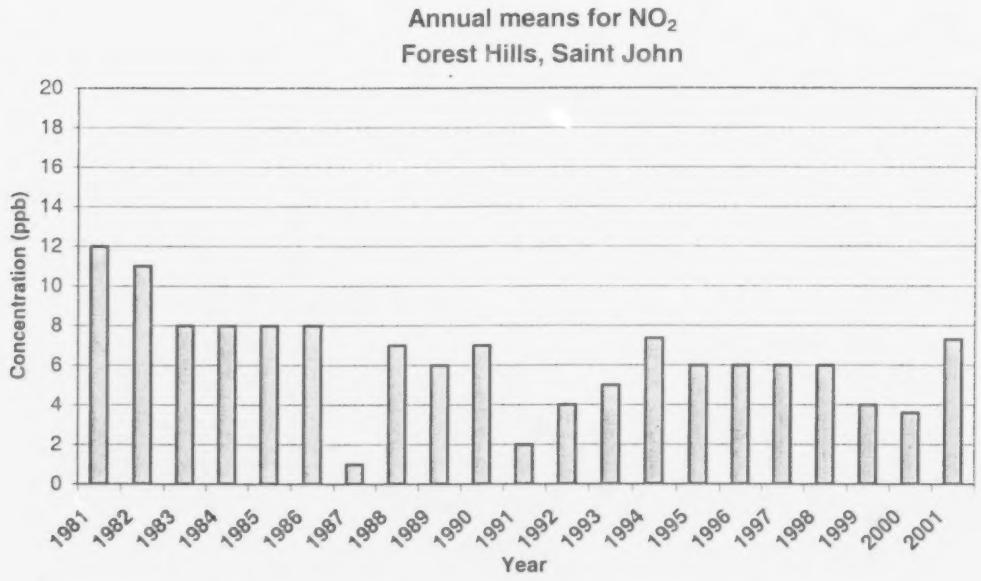


Figure 12. Annual mean nitrogen dioxide at Forest Hills, Saint John, 1981-2001.

Customs Building

Nitrogen dioxide levels appear to be stable or decreasing in recent years, following an increase from the early 1980s to 1987. In 2001, the annual mean at this uptown location was slightly higher than in 2000, There is no clear evidence of a progressive trend since 1992.

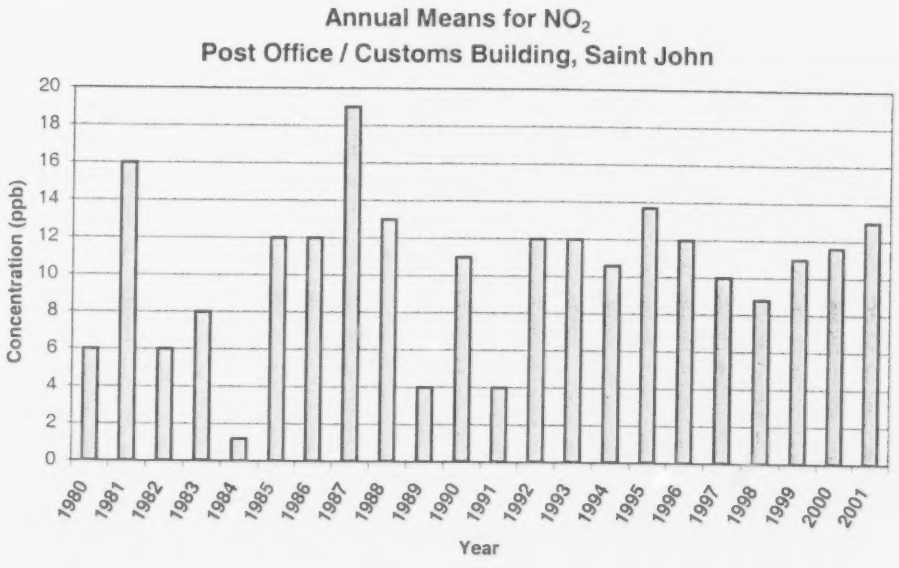


Figure 13. Annual mean nitrogen dioxide at Customs Building, Saint John, 1980-2001.

C. Sulphur dioxide

Forest Hills

Air quality monitored at the Forest Hills site in east Saint John is influenced by several local industries. Considering the trend since 1976, annual average concentrations have twice increased and decreased over the 22 year period, from 1976 to 1987 and from 1987 to 1996. In 2001, the decreasing trend which began in 2000 was continued. Influences on sulphur dioxide levels at this site include emissions from the Courtenay Bay generating station, the pulp and paper sector, the oil refinery and possibly the Coleson Cove generating station.

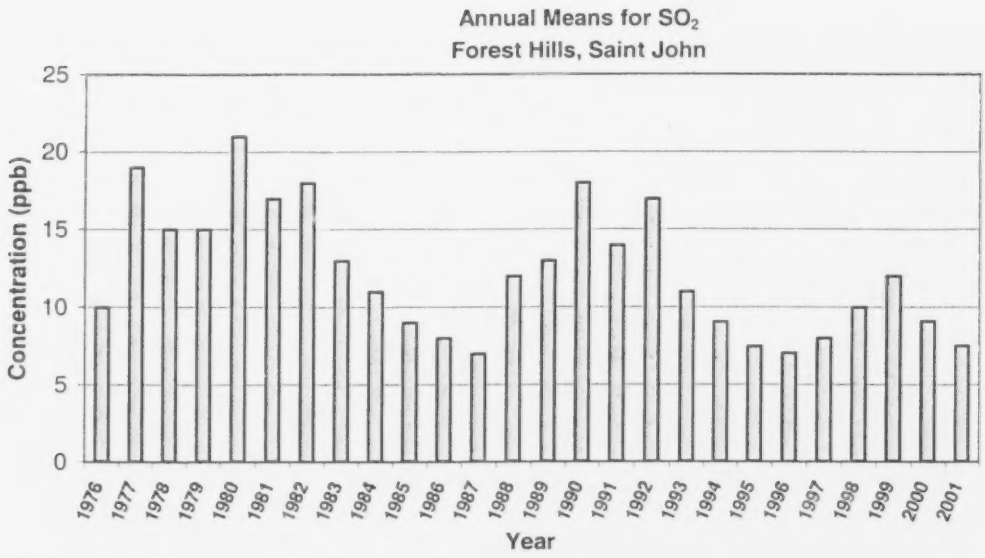


Figure 14. Annual mean sulphur dioxide at Forest Hills, Saint John, 1976-2001.

Customs Building

In uptown Saint John, as represented by records from the Post Office and Customs Building sites, the sulphur dioxide trend has been downward since the mid-1970s. Recently, levels have been approximately 30% of those common in the early 1980s. Decreasing concentrations in this part of the city are probably due to reduced emissions from the Reversing Falls pulp and paper mill, which fell by about 70% from 1980 to 1995.

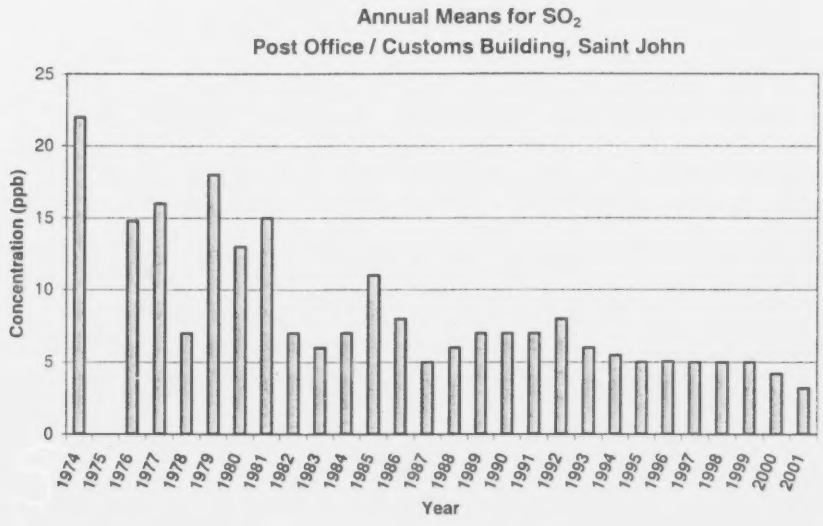


Figure 15. Annual mean sulphur dioxide at Post Office/Customs Building , Saint John, 1974-2001.

Reduced emissions from the NB Power Courtenay Bay generating station (down 74% from 1990 to 1995) may also be partly responsible. The annual mean in 2001 was down slightly from 2000, and was the lowest in the record so far.

D. Ozone

As explained in section 11, ozone is a regionally transported pollutant which is not emitted directly from smokestacks or tailpipes, but which forms in the air when other pollutants mix and react together. As such, trends in ozone are due to changing emissions of the pollution ingredients that are required for ozone to be made (nitrogen oxides and volatile organic compounds) over a large upwind area of eastern Canada and the United States. Seasonal weather, especially summer conditions, also has a major influence on the amount of ozone affecting New Brunswick.

Forest Hills

At Forest Hills, ozone levels have not changed significantly over the past 19 years. There have been some years such as 1984 and 1988 which had higher values, but there is no overall trend either up or down.

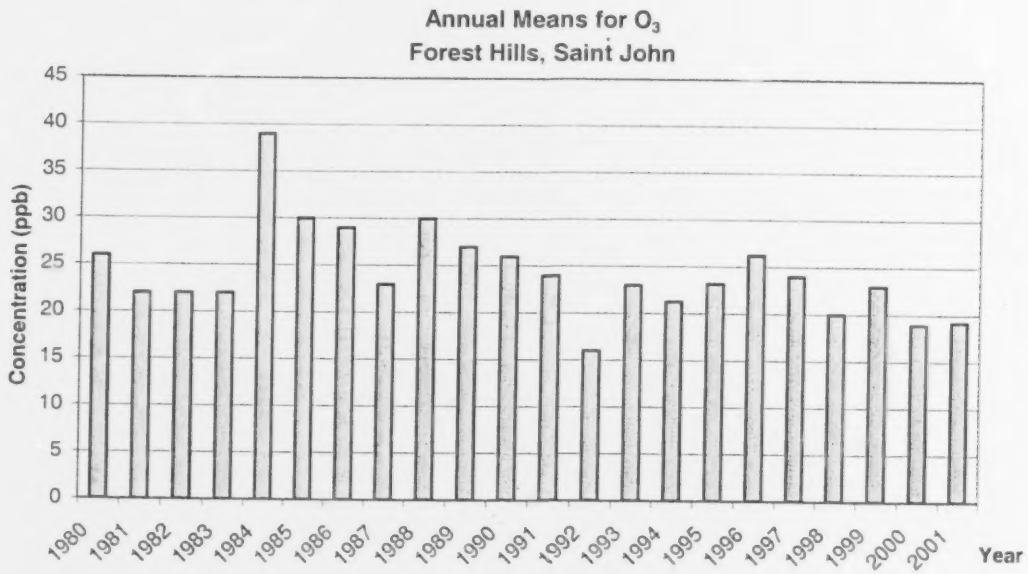


Figure 16. Annual mean ozone at Forest Hills, Saint John, 1980-2001.

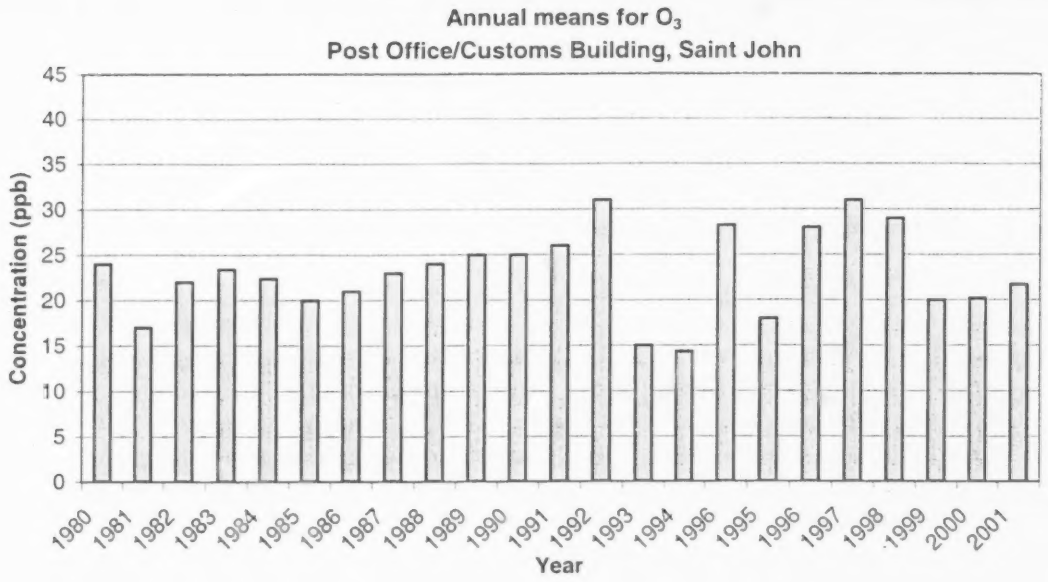


Figure 17. Annual mean ozone at Post Office/Customs Building, 1980-2001.

Customs Building

At the Customs site, annual averages for ozone have been variable since the early 1990s. Taking the most recent results into account, there is no clear trend to be seen over the period of record.

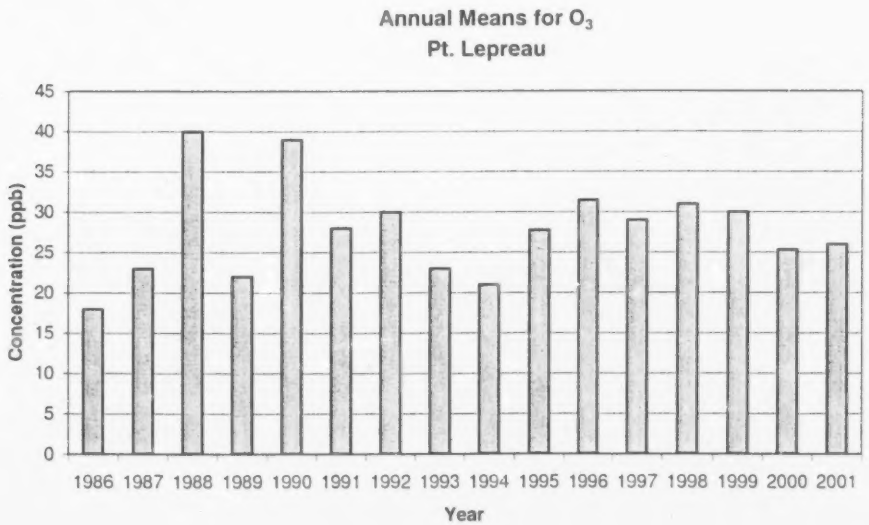


Figure 18. Annual mean ozone at Point Lepreau, 1986-2001.

Point Lepreau

Data for this site are included to provide a perspective from a rural location which is almost always upwind of major sources of air pollutants in southern New Brunswick. Annual ozone levels are somewhat higher than those seen in the Saint John area. This is due to the lack of other emissions which react with and remove ozone from the air (mainly nitric oxide).

The record at Point Lepreau reveals considerable variability between years and the indication of a possible upward trend since 1986. The 2001 results remained similar to those of the previous five years. Due to the complex relationship between ozone, its precursor compounds and weather conditions, it is very difficult to evaluate the significance of apparent trends in ozone. Within a given geographic area it is not unusual to find different trends at different sites, even though all may be apparently influenced by the same weather and pollution transport conditions. Local site factors are probably important.

E. Inhalable particulate (PM_{10})

Forest Hills

The data from Forest Hills are shown in Figure 19. Due to the effect of dust (especially road dust) on PM_{10}, some variation between years is to be expected, due to changes in weather (for example, the frequency of dry, windy conditions). In 2001 the annual average was similar to values seen over the past three to five years.

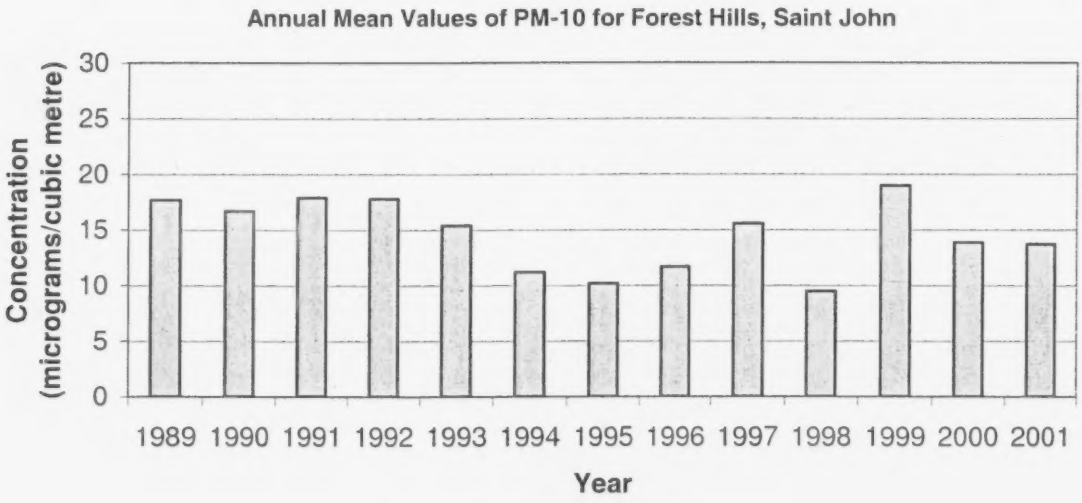


Figure 19. Annual mean PM_{10} at Forest Hills, Saint John, 1989-2001.

Note: insufficient data were obtained during 2001 from the Provincial Building and Western District sites to warrant including in the analysis of long-term trends.

F. Acid Rain

Since 1986, 27 separate sites have been operated for monitoring acid deposition across New Brunswick. Provincial coverage is presently maintained with 13 sites.

To provide a statistic which can give some indication of long term changes or trends, the annual average sulphate concentration in precipitation was averaged across all sites operating in each year. The results are shown in the accompanying chart, which also shows the number of sites operating in each year. The trend is downward since 1989. This is expected, based on reductions in sulphur dioxide emissions in eastern Canada and the United States in the same time period.

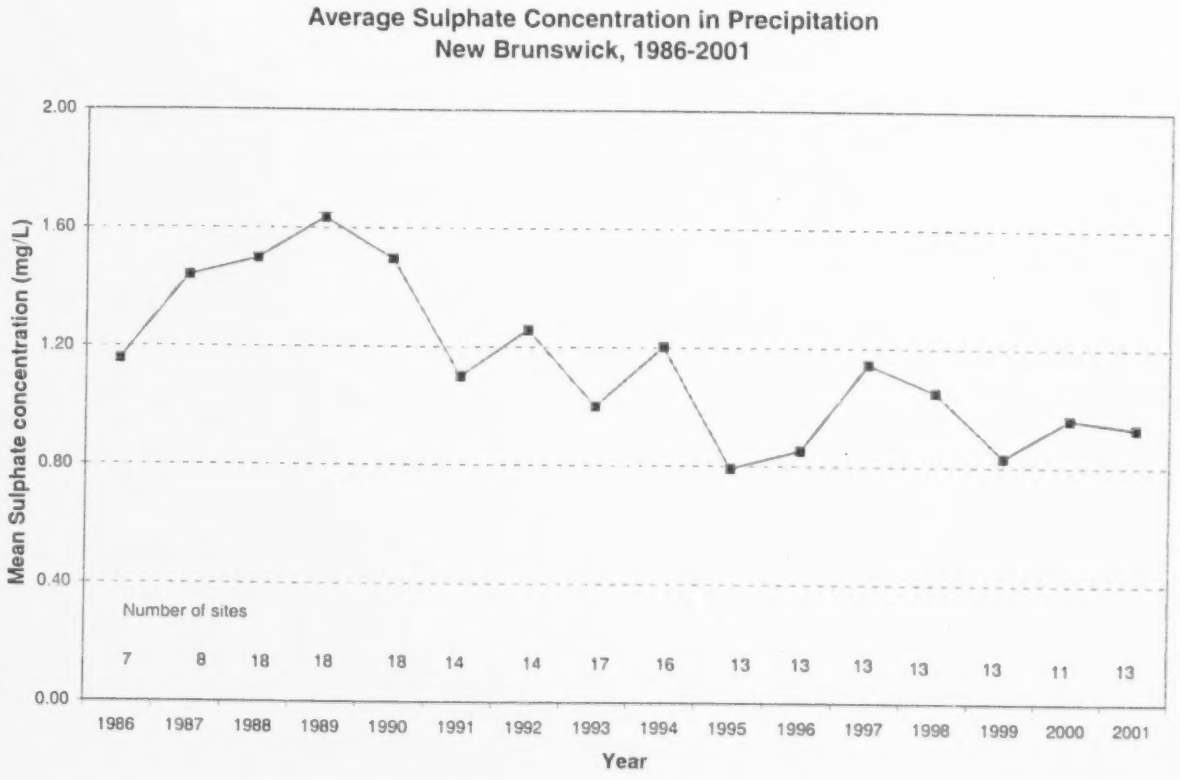


Figure 20. Network-wide mean annual sulphate concentration in precipitation in New Brunswick, 1986-2001.

G. Volatile Organic Compounds

VOCs have been measured at two locations (Forest Hills and Point Lepreau) since 1992, as noted in section 10. Routine analyses provide results for over 150 VOCs. In July 2000, sampling was begun at Champlain Heights School in east Saint John. Trends for selected VOCs are presented here.

One clear finding of the VOC sampling program is that concentrations of most VOCs are substantially higher at Forest Hills (and the new Champlain Heights location) than at Point Lepreau. This is consistent with the location of Forest Hills in an industrial urban setting and Point Lepreau in a relatively remote, rural situation.

Figure 21 shows trends in average total VOC concentrations for all sites since 1992.

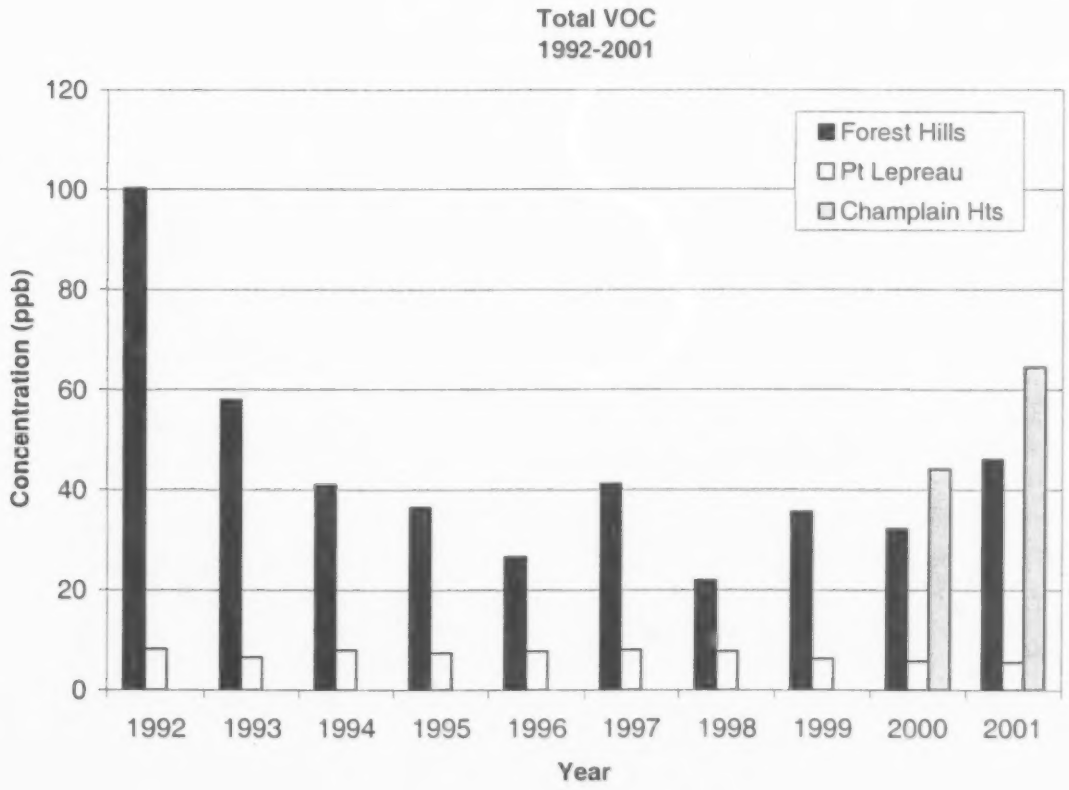


Figure 21. Average total VOC concentration at provincial VOC monitoring sites, 1992-2001.

These results clearly show the difference in average VOC levels between the sites, as well as a significant downward trend in total VOC at Forest Hills from 1992-1998. There has been relatively little change at Point Lepreau. The decrease at Forest Hills is

thought to be due to reduced levels of many individual compounds characteristic of industrial influence.

Total VOC concentrations in 2001 increased at both Forest Hills and Champlain Heights, compared with 2000. Emissions from the refinery complex clearly influence the Forest Hills location, and levels of compounds such as butane and isopentane, which are major components of gasoline vapour, have shown a downward trend over the measurement period (Figure 22). Initial results from Champlain Heights show higher values than at Forest Hills, and also increased in 2001 over values seen in 2000. At both Point Lepreau and Forest Hills, values in 2001 were similar to those in 2000, whereas values at Champlain Heights rose about 24%.

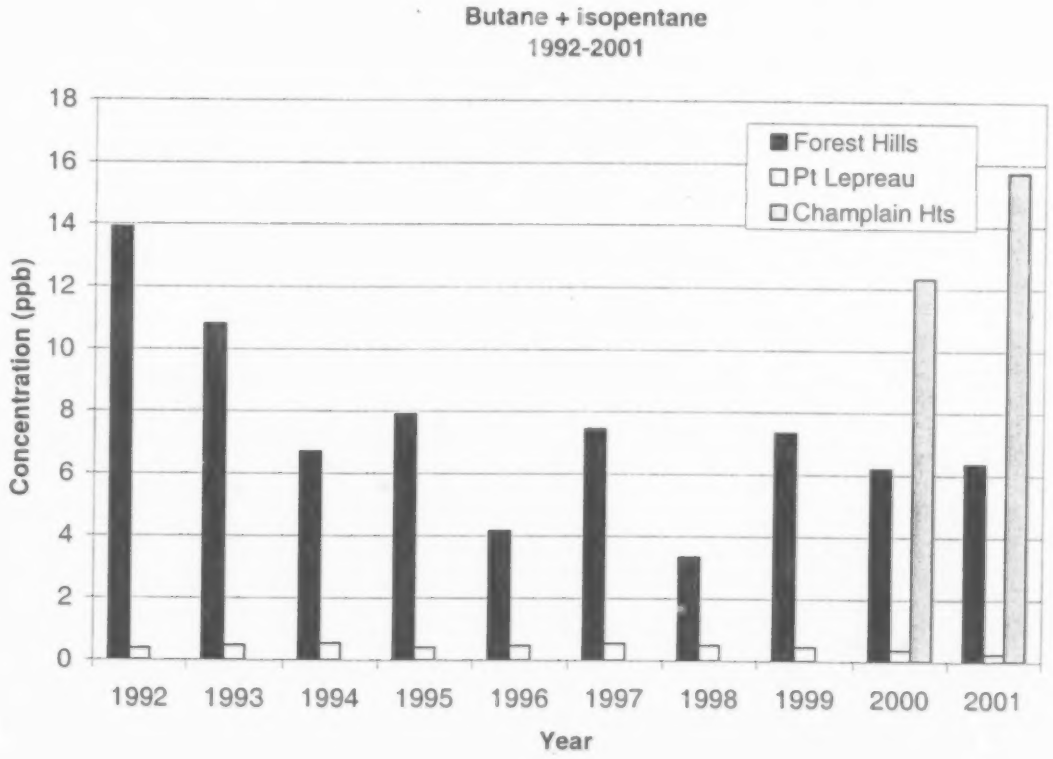


Figure 22. Annual average concentration of butane plus isopentane at provincial VOC monitoring sites, 1992-2001.

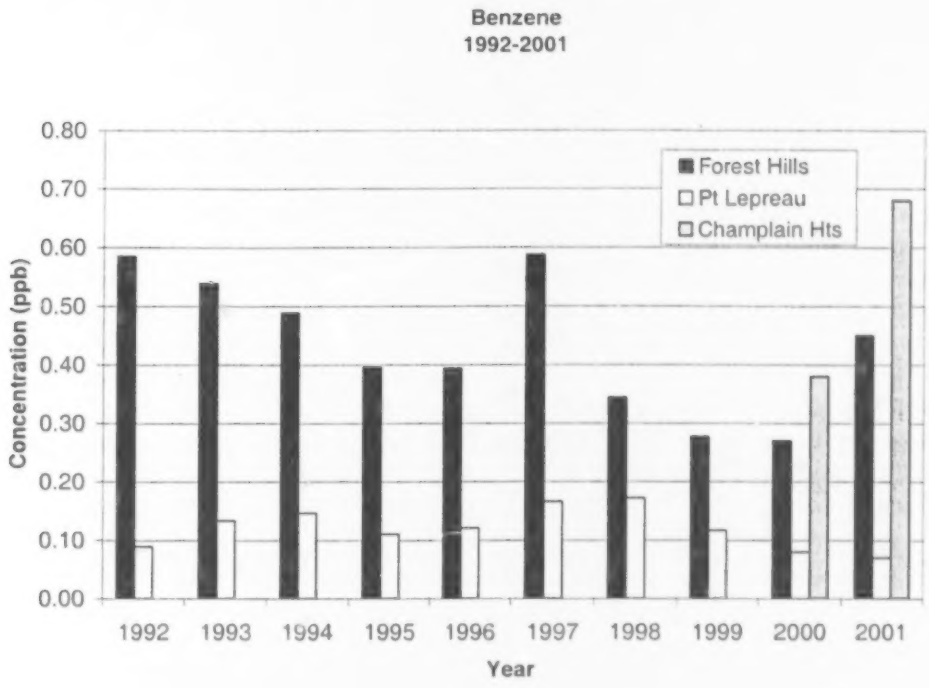


Figure 23. Annual average concentration of benzene at provincial VOC monitoring sites,1992-2001.

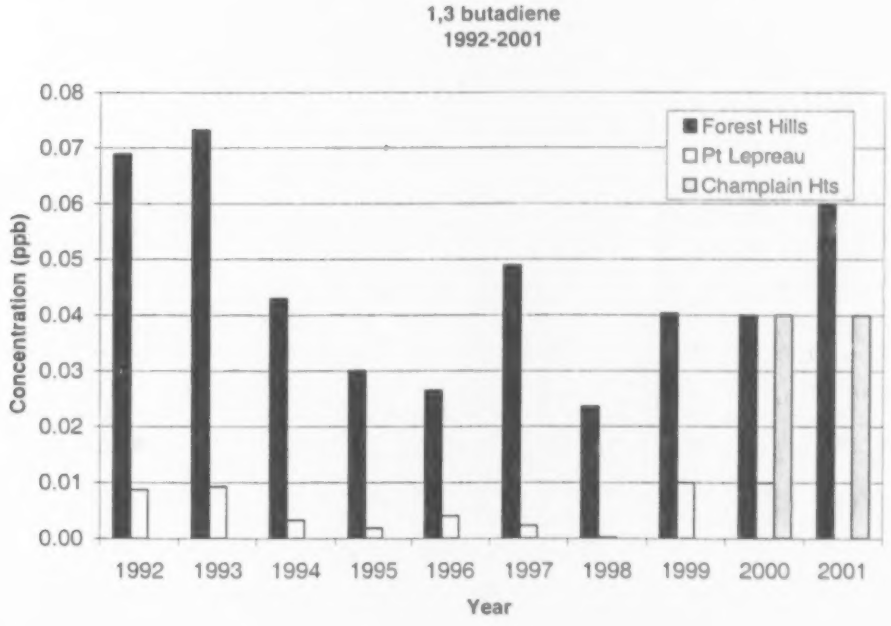


Figure 24. Annual average concentration of 1,3 butadiene at provincial VOC monitoring sites, 1992-2001.

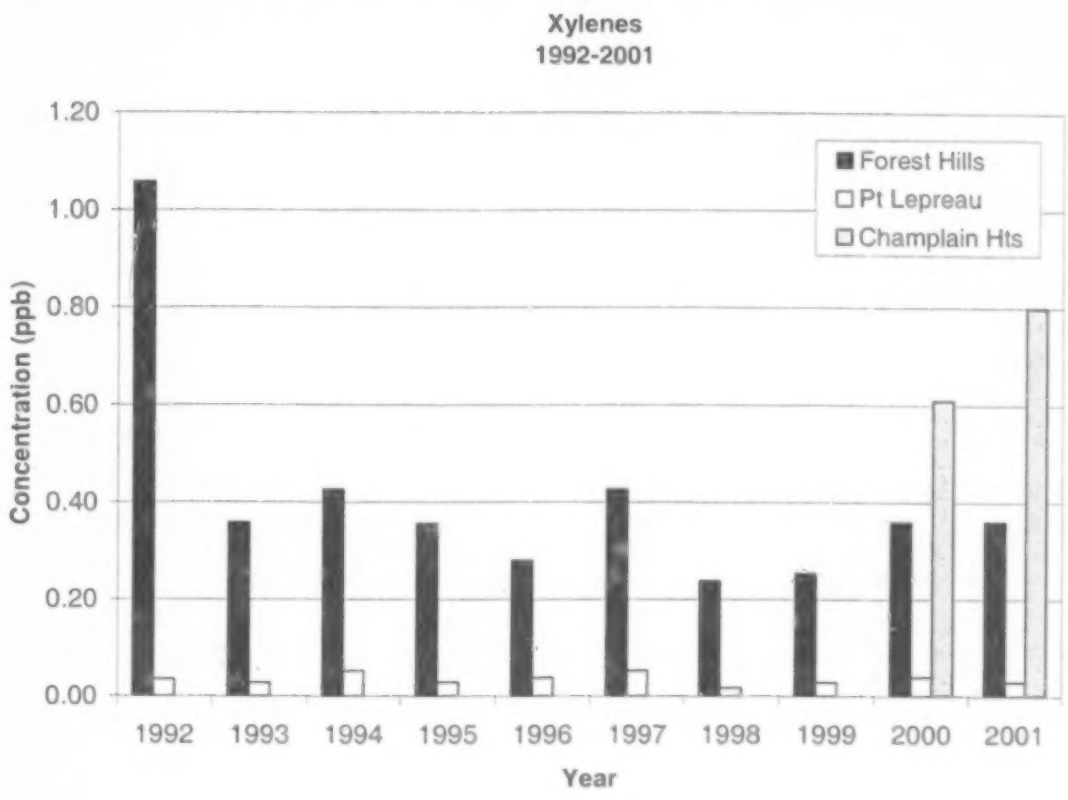


Figure 25. Annual average concentration of xylenes at provincial VOC monitoring sites, 1992-2001.

Some potentially toxic VOCs also show a generally decreasing trend at the Forest Hills monitoring site. Figure 23 shows the trend for benzene, Figure 24 for butadiene and Figure 25 for xylenes. In each case there is little apparent trend at the rural Lepreau site.

Benzene rose in 2001 at both the urban sites; butadiene rose at Forest Hills but remained unchanged at Champlain Heights. Xylenes rose at Champlain Heights but did not change at Forest Hills. Benzene is an important component of gasoline, and xylenes are associated with vehicle exhaust (Multistakeholder NOx/VOC Science Program, 1997a). Butadiene is emitted during petroleum refining and subsequent handling, as well as from internal combustion engines (e.g. CARB, 1992). The oil refinery began a leak repair program in 1995, designed to reduce VOC emissions from leaking equipment such as pumps and valves. This may have been a factor in the observed decreases of many VOCs, although the bulk of the decrease took place between 1992 and 1995. Other changes may have had some influence, such as an increasing proportion of vehicles on the road being equipped with emission control devices. The recent increases may be linked to the overall expansion of the refinery, or changes in other emission sources in the area.

APPENDIX I: GLOSSARY OF TERMS AND ABBREVIATIONS

micrograms/m^3	Microgram (of contaminant) per cubic metre (of air).
Two-way catalytic converter	A device fitted to motor vehicle exhaust systems which reduces their output of air pollutants. A 2-way converter is designed to reduce the carbon monoxide and hydrocarbon emissions. Fitted to new light duty motor vehicles sold in Canada after 1974.
Three-way catalytic converter	A 3-way converter reduces nitrogen oxides (NOx) from motor vehicle exhaust, in addition to the pollutants removed by a 2-way catalytic converter. Fitted to new light duty motor vehicles sold in Canada after 1987.
Acidic deposition	The input of acidic pollutants to the environment, usually expressed as kilograms per hectare per year of acid-forming substances such as sulphates and nitrates (see acid rain).
Acid rain	A term which refers to rain (and snow) which has become abnormally acidic due to the effects of acidifying gases such as sulphur dioxide and nitrogen dioxide.
Acid aerosols	Very small (usually invisible) airborne particles which contain acids.
Acidification	The process by which lakes, rivers or whole drainage basins can be adversely affected by continued inputs of acid rain.
Act	A broad piece of legislation which provides authority to government departments and Ministers to develop more specific regulations and policies, and carry out related enforcement activities.
Aerosol	When referring to air pollution, aerosol means small suspended particles in the air, which may be natural or resulting from human activities.
Air quality Index	A near real-time information system providing the public with an indication of overall air quality, expressed as a single number (usually on a 0-100 scale). The index takes into account measurements of several pollutants.

Ambient air	Outdoor air.
Approval to Operate	A permit issued to businesses which tells them what they must do to comply with environmental protection requirements. For example these permits specify allowable emissions of various substances, how often reports must be made to the NBDELG, what these reports must contain, and mandatory annual testing.
ARMA committee	Air Resource Management Area Committee. Several such committees have been formed in New Brunswick since 1994, to examine local air quality issues and submit recommendations to the Minister of the Environment and Local Government.
Asthma	A disorder of the respiratory system, associated with difficulty in breathing.
Bronchitis	Inflammation of the small bronchial tubes in the lungs, which may be associated with breathing difficulties, discomfort or coughing.
Carbon monoxide	Abbreviation: CO. A colourless, odourless, toxic gas formed when fuels burn inefficiently.
CO	Carbon monoxide.
Cardiovascular	Having to do with the heart and blood circulation system.
Catalytic converter	In a motor vehicle, a device for converting harmful exhaust gases into less harmful substances. These converters use a chemical catalyst which causes the chemical conversion to take place. See 2- and 3-way catalytic converter.
Certificate of Approval	See Approval to Operate.
Clean Air Strategy	A policy document of the NBDELG, published in 1993, reviewing air quality in New Brunswick and setting out directions for future efforts to improve it.
Corridor	In air pollution terminology, refers to a region through which prevailing winds frequently pass, carrying air pollutants. For example the Windsor-Quebec City corridor, the Washington-Boston corridor.

Critical load	Referring to acid rain, the amount of acid input a region can receive which results in no long term adverse affects to at least 95% of its lakes.
Emphysema	A condition in which the air sacs in the lungs are abnormally enlarged, causing lack of breath.
Episode control program	An agreed-upon system of actions to be taken by an industry or other source or air contaminants, designed to prevent the occurrence of exceedances.
Exceedance	When referring to air pollution, an occasion on which a specified air quality standard or objective was surpassed. Note that hourly exceedances refer to measurements made over standard clock hours.
Geometric mean	A way of calculating a meaningful average from data which contains extreme values.
Ground level ozone	Ozone found in the air in the lower atmosphere, including the air we breathe. See ozone.
Guideline	A recommended value, but one which usually does not have the force of law. See objective.
H_2S	Hydrogen sulphide.
Hydrocarbon	A compound containing only hydrogen and carbon. For example methane, propane and butane are all hydrocarbons.
Hydrogen sulphide	Abbreviation: H_2S. A toxic gas, smelling powerfully of rotten eggs, detectable by the human nose at very low concentrations. Formed by some paper making processes and also found in sewer gases and naturally in swamps and marshes, where it is produced by decomposing plants.
Inhalable particles	Particles of soot, dust etc., which are small enough that they may enter the lungs without being filtered out by the nose and throat.
IQUA	Index of the Quality of the Air. A system used in Saint John since 1979 to provide the public with a reference indicator for air quality. See Air Quality Index.

kg	Kilogram.
Long range transport	In air pollution terminology, refers to the movement of air pollutants by prevailing winds and weather systems hundreds or thousands of kilometres from where they are released.
Microgram	A millionth of a gram.
Modelling	In the context of air pollution, this terms refers to computer modelling: using simulations of the atmosphere and other natural processes to explore the probable outcome of changing pollution emissions, or the impact of other factors such as weather on pollution levels.
NAAQO	National Ambient Air Quality Objective. Nationally recommended guideline concentrations for air contaminants, designed to provide protection of human health and the environment generally.
Nanogram	A thousand-millionth of a gram or 10^{-9} grams.
NBDELG	The New Brunswick Department of the Environment and Local Government.
Nitrogen oxides	Compounds of nitrogen and oxygen, primarily referring to nitric oxide and nitrogen dioxide. Abbreviation: NOx.
NOx	See nitrogen oxides.
NO_2	Nitrogen dioxide.
Objective	In the context of air quality, a management goal for environmental protection, usually stated as a number (see the definition for guideline). Objectives may also be broader in nature and expressed as plain language statements. Objectives do not normally have legal force.
Ozone	Abbreviation: O_3. A colourless gas, formed from three oxygen atoms, having a sharp odour at high concentrations. Ozone is very chemically active and can damage living plant and animal cells. Ozone is a major component of photochemical smog, and is formed in this situation by reactions between other air pollutants.
O_3	Ozone

Particulate	A very small piece of soot, smoke or dust; by inference, one which is small enough to become airborne.
Percentile	A statistical term used to classify data according to the frequency of occurrence of a given result. For example, the 50^{th} percentile of a dataset is equal to the mean, or average value. The 75^{th} percentile value is the value which is equal to or greater than 75% of all the measurements contained in that dataset.
Photochemical smog	A mixture of air pollutants usually containing ozone, nitrogen oxides, and particulates. Seen over or downwind of major city areas, typically in hot, sunny weather together with light winds. Often visible against a clear sky as a whitish, yellow or brown cloud or layer.
Picogram	One million-millionth of a gram, or 10^{-12} grams.
ppb	Parts (of contaminant) per billion (parts of air).
ppm	Parts (of contaminant) per million (parts of air).
pphm	Parts (of contaminant) per hundred million (parts of air).
PM_{10}	Particulate matter where the individual particles have an effective diameter of 10 microns (millionths of a metre) or less. These particles are small enough to be bypass filtration by the nose and may enter the lungs.
$PM_{2.5}$	Particulate matter where the individual particles have an effective diameter of 2.5 microns (millionths of a metre) or less. These particles may be deposited in the lungs if inhaled.
Radiation balance	The process by which the earth remains at a more or less constant temperature, by radiating as much heat into space as it receives from the sun. So-called greenhouse gases (such as carbon dioxide or methane) affect this balance by slowing down the loss of heat from the lower atmosphere.
Regulation	A formal legal document, made with the authority of an Act, which specifies rules in more technical detail than is given in the Act itself.

Smog advisory	A public information message providing details of expected ground level ozone pollution in the following 24 hours. A smog advisory program has operated in New Brunswick since 1993.
Smog	Originally, a mixture of smoke and fog. Now more often used to refer to pollution mixtures containing ozone and fine particles. See photochemical smog.
SO_2	Sulphur dioxide.
Standard	A numeric value used for the purpose of environmental management: usually refers to an acceptable concentration of a contaminant. Differs from a guideline, goal or objective by having legal force.
Sulphur dioxide	A gas generated when sulphur-containing fuels are burned, having a characteristic, acrid smell. One of the most widespread air pollutants around the world, associated with heavy industry (e.g. smelting, oil refining and major fuel combustion in generating stations).
Target load	Referring to the issue of acid deposition, an interim goal for environmental protection.
TEOM	A type of continuous measuring device for monitoring the particulate content of ambient air. Refers to the measurement principle (Tapered Element Oscillating Microbalance).
TSP	Total suspended particulate.
Total suspended particulate	Abbreviation: TSP. A standard measure of particle concentration in the air. Includes smoke, soot, pollen and other dust from about 0.1 up to approx. 50 microns in diameter.
Trajectory analysis	A method for following the movement of air over long distances, enabling the probable source regions of pollutants to be identified.
VOC	Abbreviation for volatile organic compound. Includes carbon-containing substances which evaporate readily at normal environmental temperatures, examples include gasoline, the solvents in paint, nail polish remover, and many natural VOCs.

APPENDIX II: CANADIAN NATIONAL AIR QUALITY OBJECTIVES

Canadian National Air Quality Objectives

		Sulphur Dioxide	TSP	Carbon Monoxide	Ozone	Nitrogen Dioxide	Hydrogen Sulphide (Proposed)
		ppb	$\mu g/m^3$	ppm	ppb	ppb	ppb
Maximum Tolerable Level[1]	1 h				153	532	
	8 h			17.5			
	24 h	306	400			160	
	1 yr.						
Maximum Acceptable Level[2]	1 h	344		30.6	82	213	10.8
	8 h			13.1			
	24 h	115	120		25	106	3.6
	1 yr.	23	70		15	53	
Maximum Desirable Level[3]	1 h	172		13.1	51		0.7
	8 h			5.2			
	24 h	57			15		
	1 yr.	11	60			0.03	

Notes: 1. The maximum tolerable level denotes a concentration of an air pollutant that requires abatement without delay to avoid further deterioration to air quality that poses a substantial risk to public health.

2. The acceptable level is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well being.

3. The desirable level defines the long-term goal for air quality and provides the basis for an anti-degradation policy for the unpolluted parts of the country.

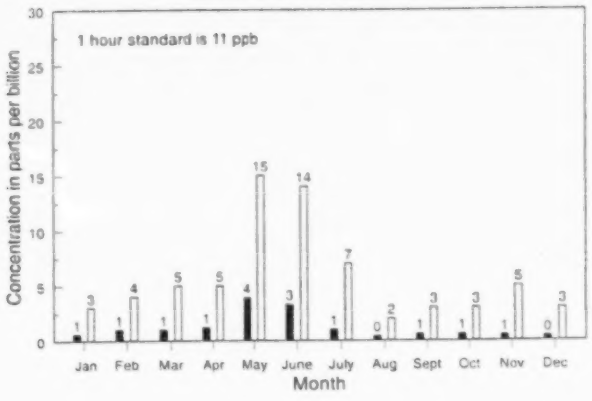
TSP : Total suspended particulate.

$\mu g/m^3$: Micrograms per cubic metre.

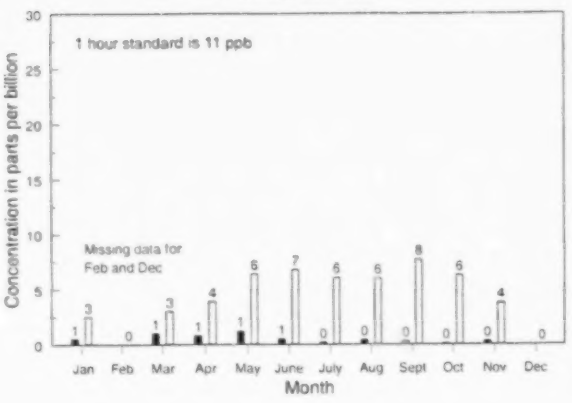
APPENDIX III

DETAILED MONTHLY MONITORING RESULTS FOR 2001

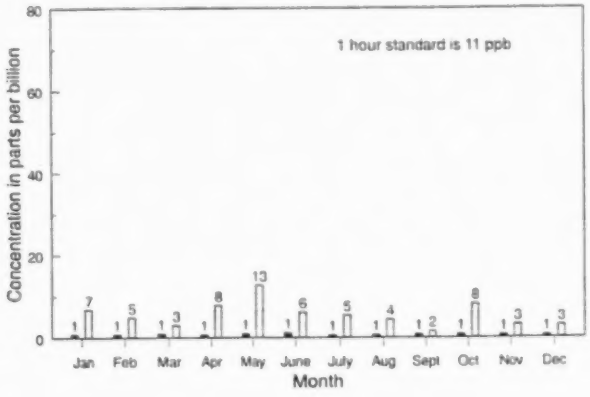
Monthly Average & Maximum One Hour Values of Total Reduced Sulphur in 2001
Sherbrooke Street - Saint John



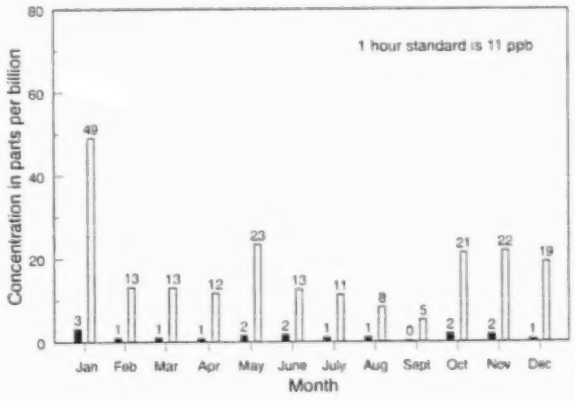
Monthly Average & Maximum One Hour Values of Total Reduced Sulphur in 2001
Ste. Anne-Nackawic


1 hour standard is 11 ppb
Missing data for Feb and Dec
Concentration in parts per billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

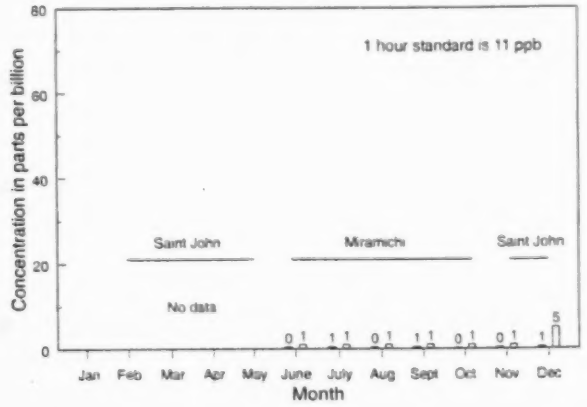
Monthly Average & Maximum One Hour Values of Total Reduced Sulphur in 2001
UPM Groundwood Mill - Miramichi



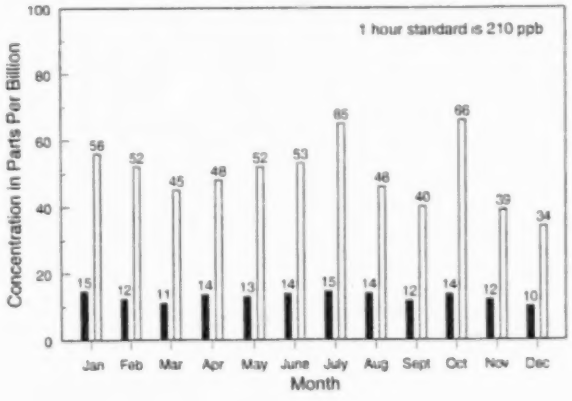
Monthly Average & Maximum One Hour Values of Total Reduced Sulphur in 2001
UPM King George Highway - Miramichi



Monthly Average & Maximum One Hour Values of Total Reduced Sulphur in 2001
Mobile Unit

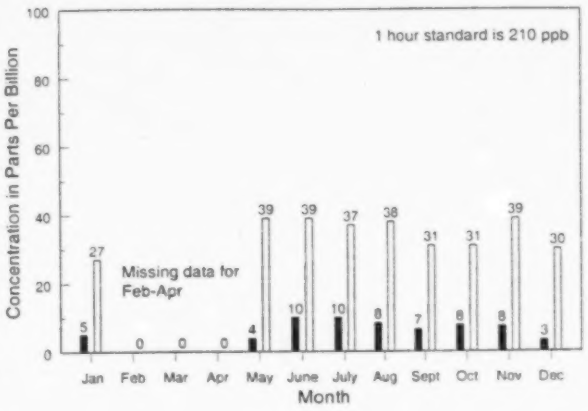


Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001
Customs Building - Saint John



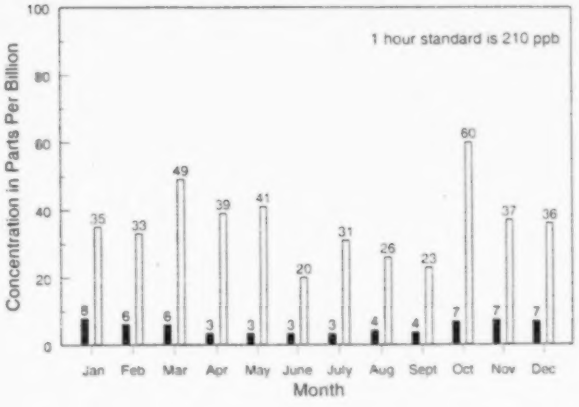
Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001

Forest Hills - Saint John


1 hour standard is 210 ppb
Missing data for Feb-Apr
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
5 27 0 0 0 4 39 10 39 10 37 8 38 8 31 7 31 8 39 8 30 3

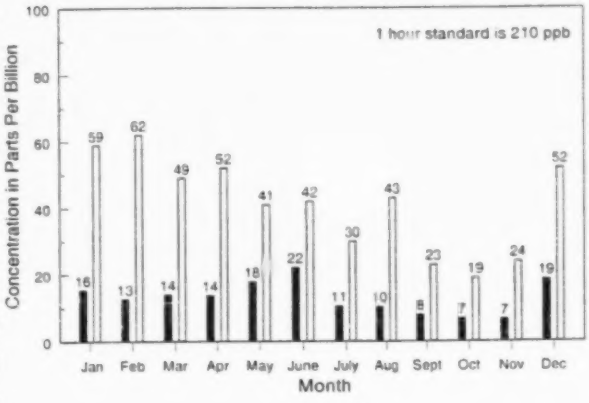
Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001

Champlain Heights - Saint John


1 hour standard is 210 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
8 35 6 33 6 49 3 39 3 41 3 20 3 31 4 26 4 23 7 60 7 37 7 36

Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001

Highfield St. - Moncton


1 hour standard is 210 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
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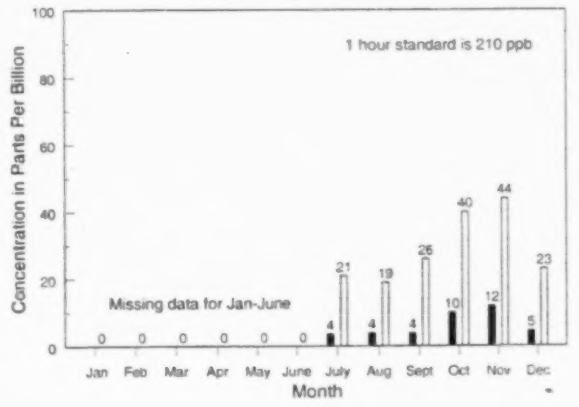
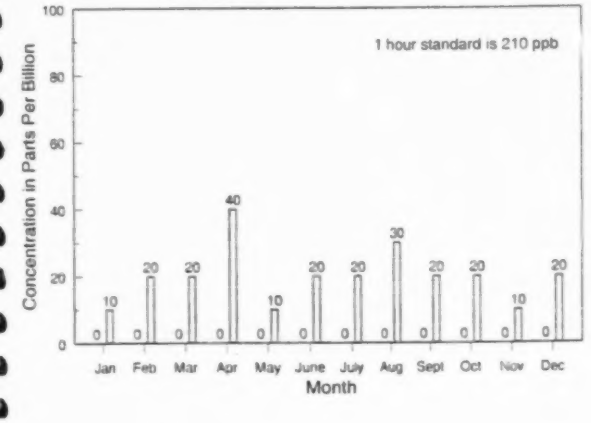
Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001

Aberdeen St. - Fredericton


1 hour standard is 210 ppb
Missing data for Jan-June
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 0 0 0 0 0 4 21 4 19 4 26 10 40 12 44 5 23

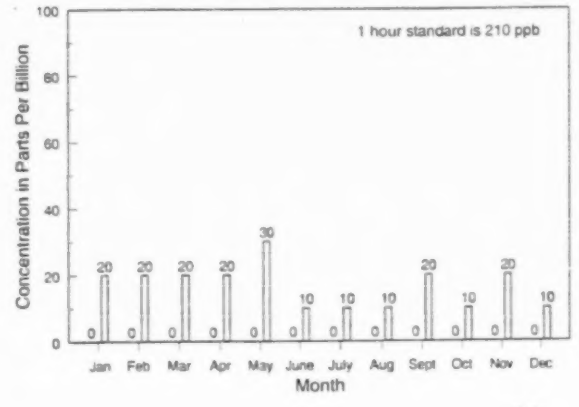
Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001

NB Power Belledune - Belledune East

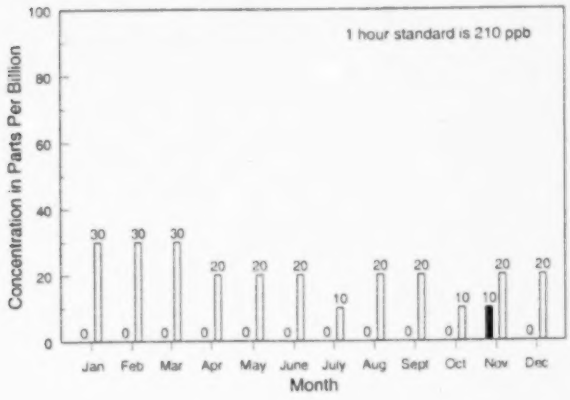

1 hour standard is 210 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 10 0 20 0 20 0 40 0 10 0 20 0 20 0 30 0 20 0 20 0 10 0 20

Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001

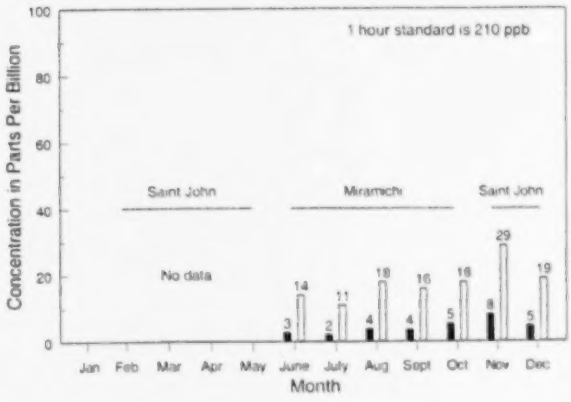
NB Power Belledune - Municipal Hall


1 hour standard is 210 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 20 0 20 0 20 0 20 0 30 0 10 0 10 0 10 0 20 0 10 0 20 0 10

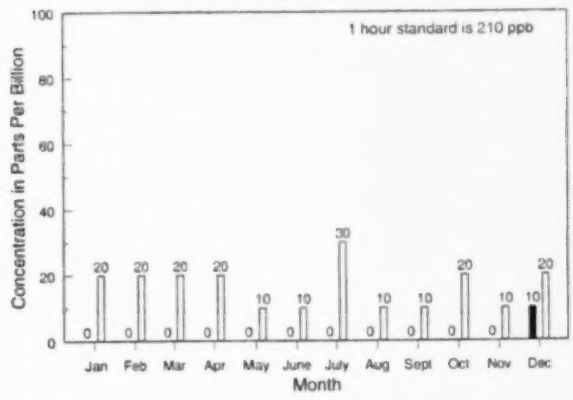
Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001
NB Power Millbank - Rockcliff


1 hour standard is 210 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 30 30 30 20 20 20 10 20 20 10 20 20
0 0 0 0 0 0 0 0 0 0 10 10 0

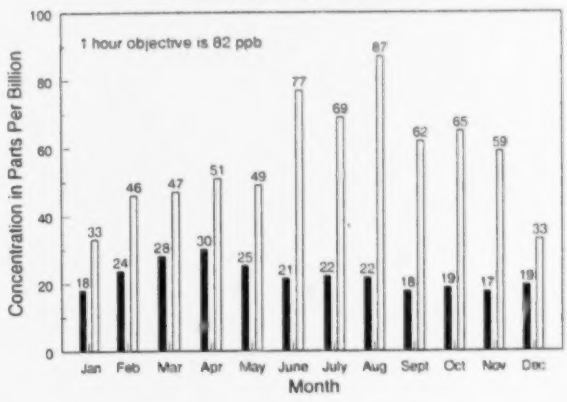
Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001
Mobile Unit


1 hour standard is 210 ppb
Concentration in Parts Per Billion
Saint John
Miramichi
Saint John
No data
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
3 14 2 11 4 18 4 16 5 18 8 29 5 19

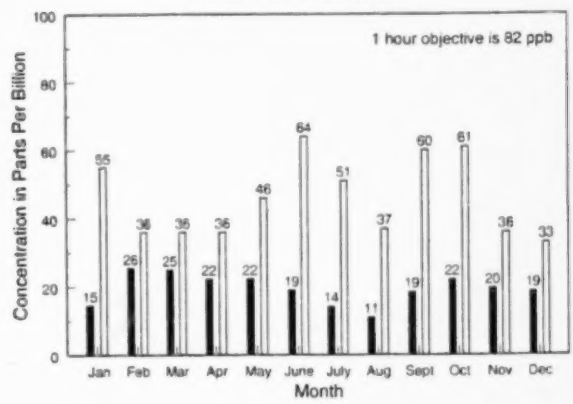
Monthly Average & Maximum One Hour Values of Nitrogen Dioxide in 2001
NB Power Millbank - Lower Newcastle


1 hour standard is 210 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 20 20 20 20 10 10 30 10 10 20 10 20
0 0 0 0 0 0 0 0 0 0 0 10 10

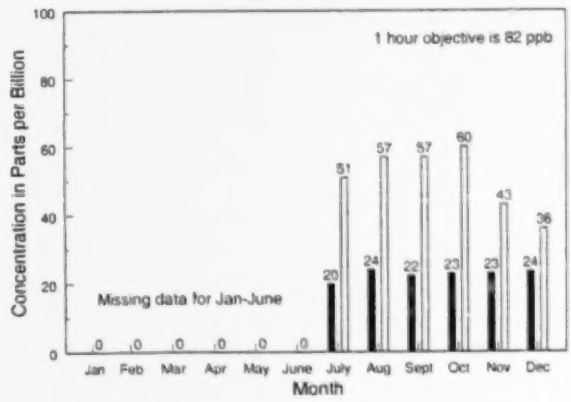
Monthly Average and Maximum One Hour Values of Ozone in 2001
Customs Building - Saint John


1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
18 33 24 46 28 47 30 51 25 49 21 77 22 69 22 87 18 62 19 65 17 59 19 33

Monthly Average & Maximum One Hour Values of Ozone in 2001
Forest Hills - Saint John

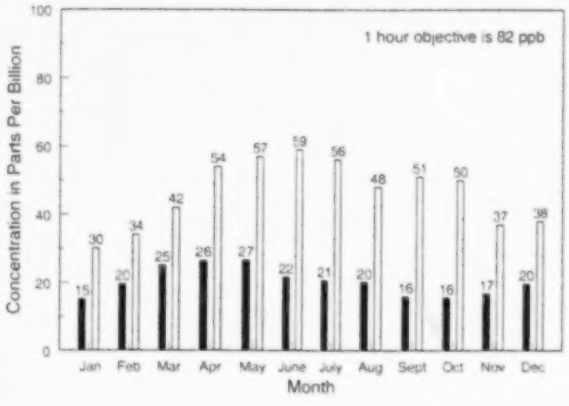

1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
15 55 25 36 25 35 22 36 22 46 19 64 14 51 11 37 19 60 22 61 20 36 19 33

Monthly Average & Maximum One Hour Values of Ozone in 2001
Canterbury


1 hour objective is 82 ppb
Concentration in Parts per Billion
Missing data for Jan-June
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 0 0 0 0 0 20 51 24 57 22 57 23 60 23 43 24 36

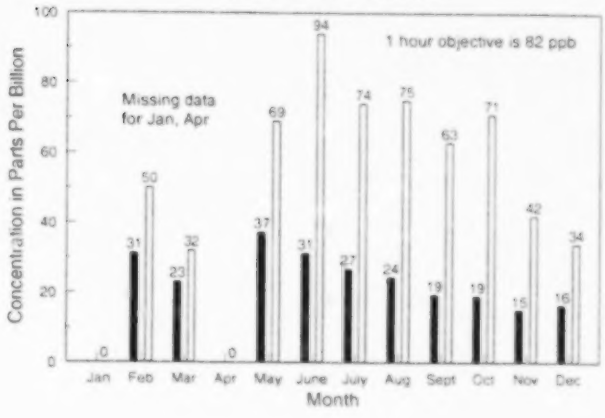
Monthly Average & Maximum One Hour Values of Ozone in 2001

Aberdeen St - Fredericton


1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
15 20 25 26 27 22 21 20 16 16 17 20
30 34 42 54 57 59 56 48 51 50 37 38

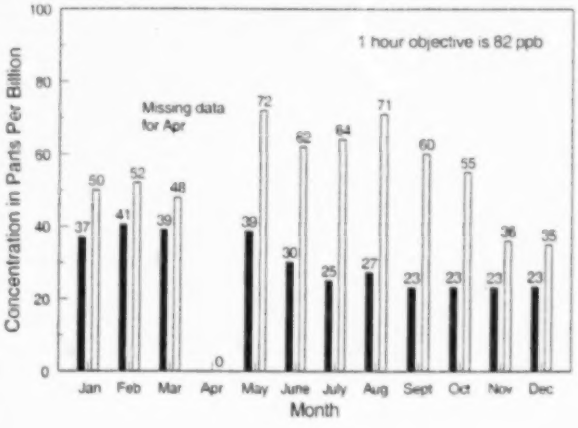
Monthly Average & Maximum One Hour Values of Ozone in 2001

Highfield St - Moncton


1 hour objective is 82 ppb
Missing data for Jan, Apr
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 31 23 0 37 31 27 24 19 19 15 15
0 50 32 0 69 94 74 75 63 71 42 34

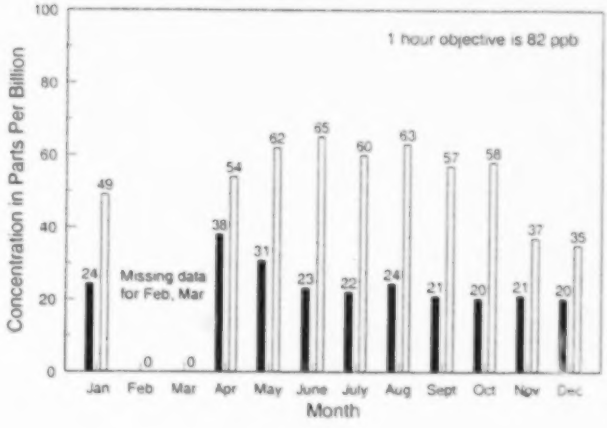
Monthly Average & Maximum One Hour Values of Ozone in 2001

St Leonard


1 hour objective is 82 ppb
Missing data for Apr
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
37 41 39 0 39 30 25 27 23 23 23 23
50 52 48 0 72 62 64 71 60 55 36 35

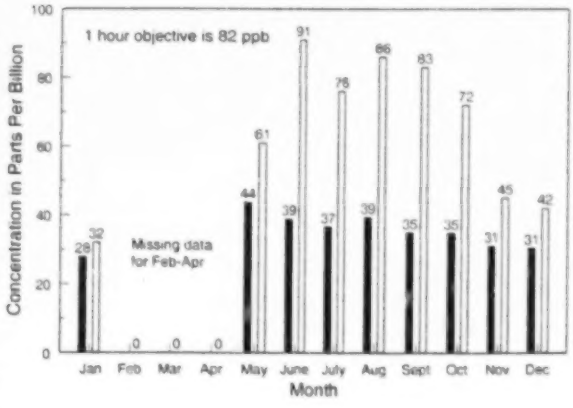
Monthly Average & Maximum One Hour Values of Ozone in 2001

Lower Newcastle - Miramichi


1 hour objective is 82 ppb
Missing data for Feb, Mar
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
24 0 0 38 31 23 22 24 21 20 21 20
49 0 0 54 62 65 60 63 57 58 37 35

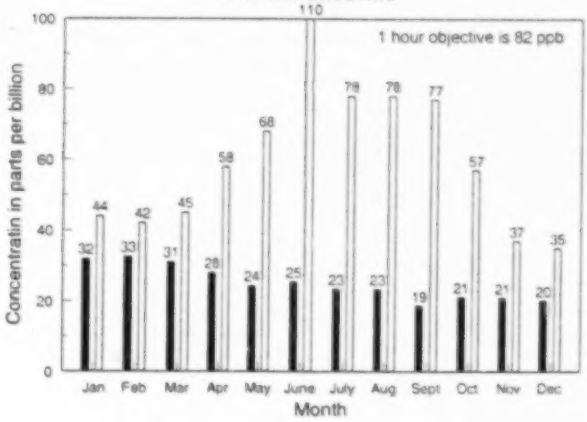
Monthly Average & Maximum One Hour Values of Ozone in 2001

Fundy Park


1 hour objective is 82 ppb
Missing data for Feb-Apr
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
28 0 0 0 44 39 37 39 35 35 31 31
32 0 0 0 61 91 78 86 83 72 45 42

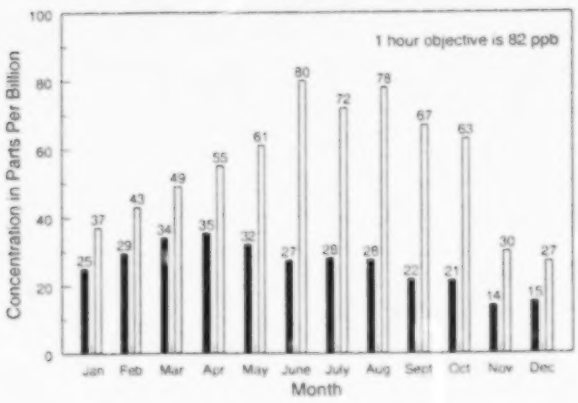
Monthly Average & Maximum One Hour Values of Ozone in 2001

Central Blissville


1 hour objective is 82 ppb
Concentratin in parts per billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
32 33 31 28 24 25 23 23 19 21 21 20
44 42 45 58 68 110 78 78 77 57 37 35

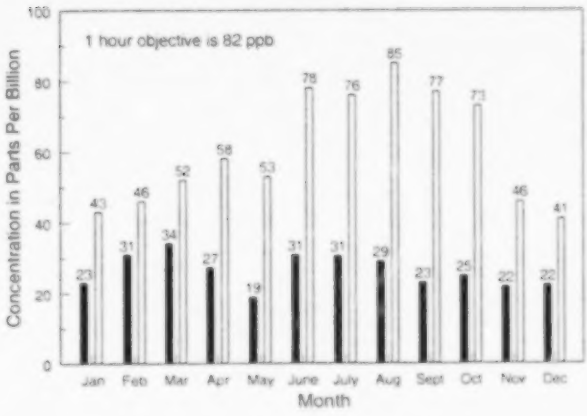
Monthly Average & Maximum One Hour Values of Ozone in 2001

Pt. Lepreau


1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
25 29 34 35 32 27 28 28 22 21 14 15
37 43 49 55 61 80 72 78 67 63 30 27

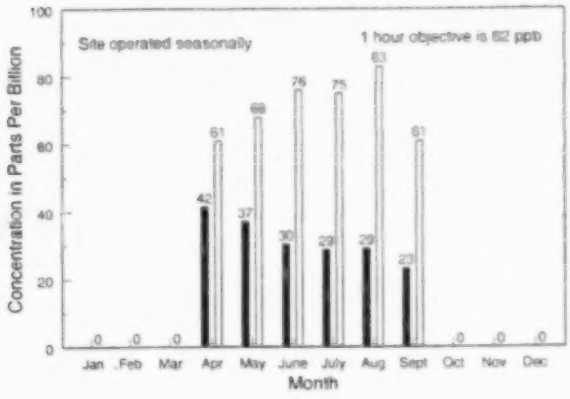
Monthly Average & Maximum One Hour Values of Ozone in 2001

Norton


1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
23 31 34 27 19 31 31 29 23 25 22 22
43 46 52 58 53 78 76 85 77 73 46 41

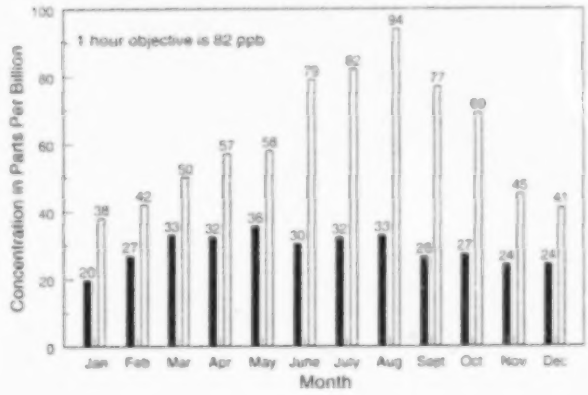
Monthly Average & Maximum One Hour Values of Ozone in 2001

Campobello


Site operated seasonally
1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 0 0 42 37 30 29 29 23 0 0 0
61 68 75 75 83 61

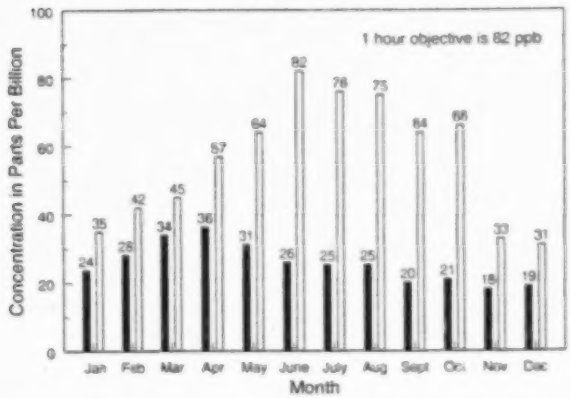
Monthly Average & Maximum One Hour Values of Ozone in 2001

Hillcrest -Saint John


1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
20 27 33 32 36 30 33 33 28 27 24 24
38 42 50 57 58 79 82 94 77 69 45 41

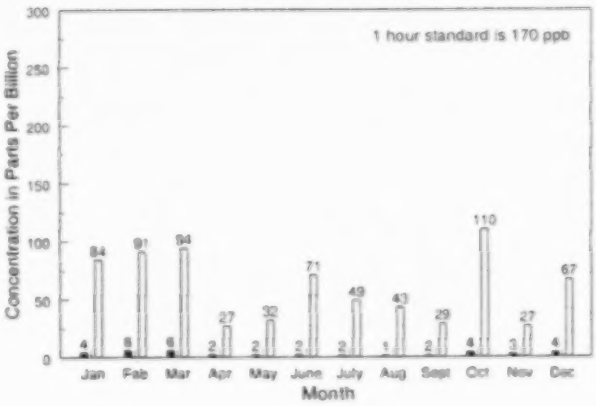
Monthly Average & Maximum One Hour Values of Ozone in 2001

St Andrews


1 hour objective is 82 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
24 28 34 36 31 26 25 25 20 21 18 19
35 42 45 57 64 82 78 75 64 68 33 31

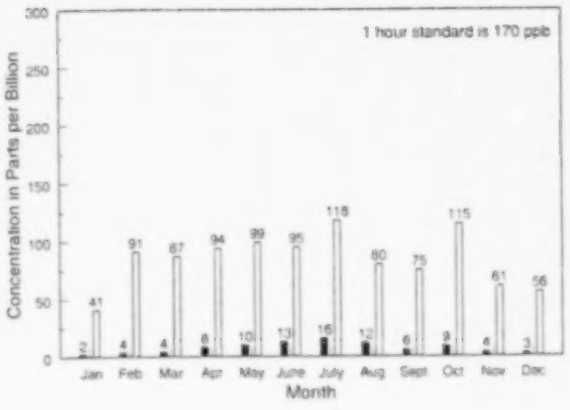
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Customs Building - Saint John


1 hour standard is 170 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
4 6 6 2 2 2 2 1 2 4 3 4
84 91 94 27 32 71 49 43 29 110 27 67

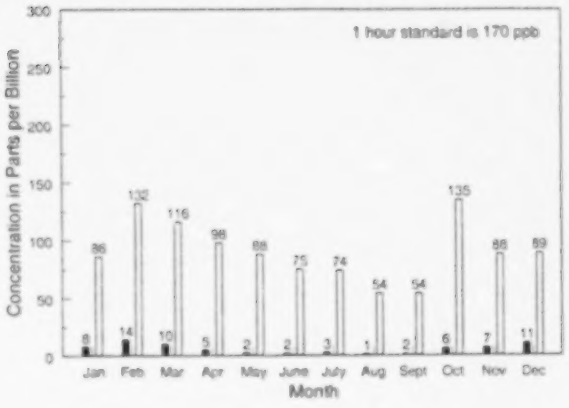
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Forest Hills - Saint John


1 hour standard is 170 ppb
Concentration in Parts per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
2 4 4 6 10 13 16 12 6 9 4 3
41 91 87 94 99 95 118 80 75 115 61 56

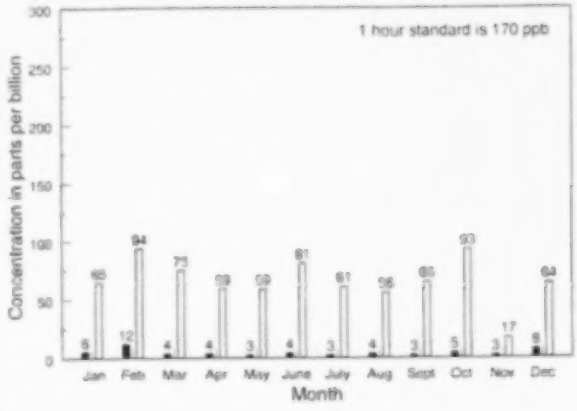
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Forest Products-Saint John


1 hour standard is 170 ppb
Concentration in Parts per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
8 14 10 5 2 2 3 1 2 6 7 11
86 132 116 98 88 75 74 54 54 135 88 89

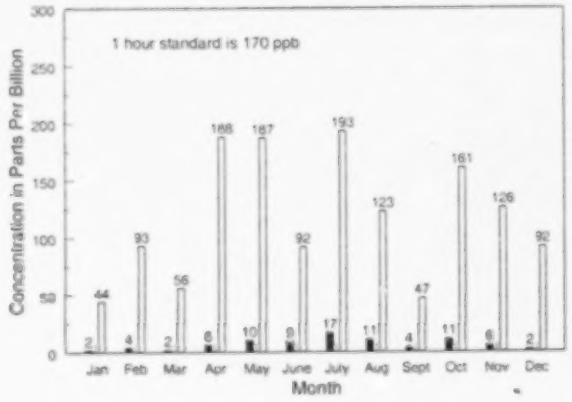
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

West Side Station (Hillcrest) - Saint John


1 hour standard is 170 ppb
Concentration in parts per billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
6 12 4 4 3 4 3 4 3 5 3 6
66 94 73 59 59 81 61 56 65 93 17 64

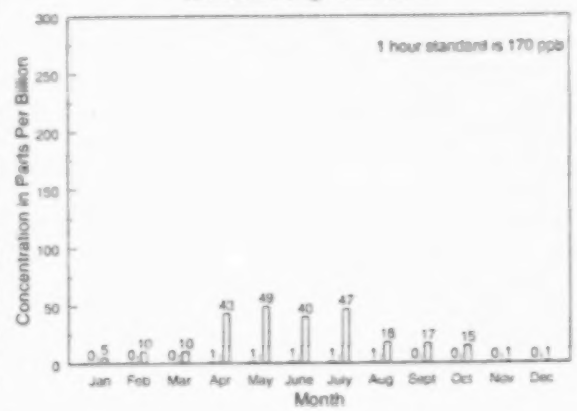
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Silver Falls - Saint John


1 hour standard is 170 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
2 4 2 6 10 9 17 11 4 11 6 2
44 93 56 188 187 92 193 123 47 161 126 92

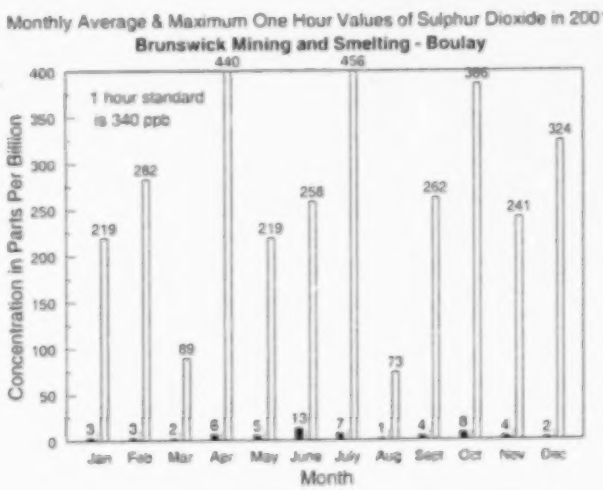
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Three Mile Irving - Saint John


1 hour standard is 170 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0.5 0.0 0.0 1 1 1 1 1 0 0 0.1 0.1
0.5 10 10 43 49 40 47 18 17 15

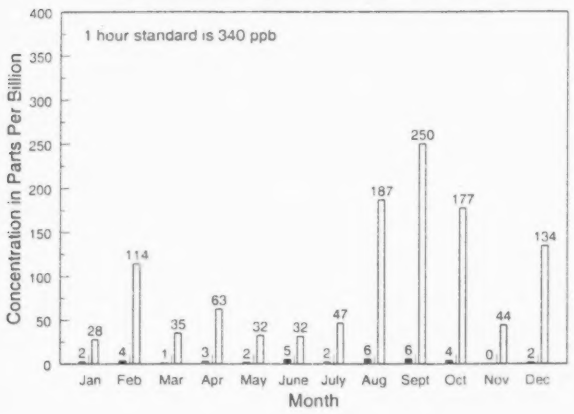
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Brunswick Mining and Smelting - Boulay


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
3 3 2 6 5 13 7 1 4 8 4 2
219 282 89 440 219 258 456 73 262 386 241 324

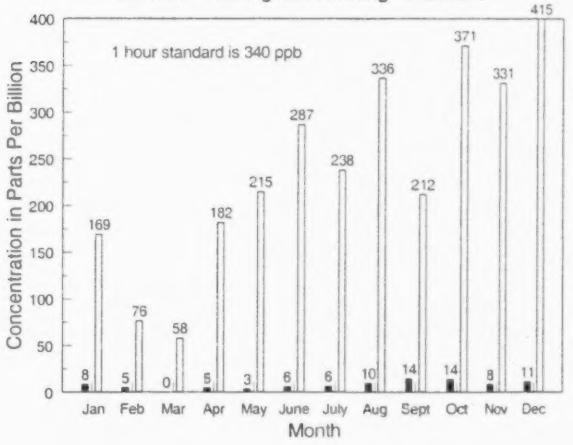
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Brunswick Mining and Smelting - Townsite


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
2 28 4 114 1 35 3 63 2 32 5 32 2 47 6 187 6 250 4 177 0 44 2 134

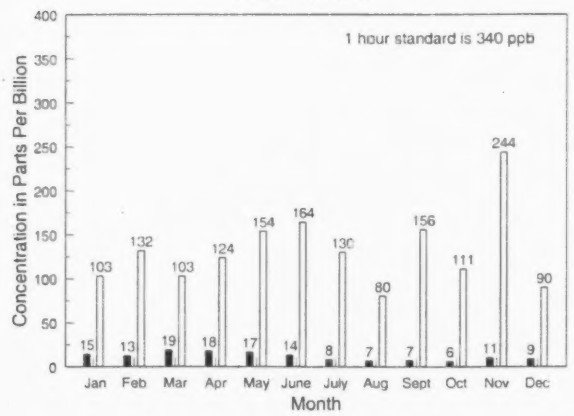
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Brunswick Mining and Smelting - Chalmers


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
8 169 5 76 0 58 5 182 3 215 6 287 6 238 10 336 14 212 14 371 8 331 11 415

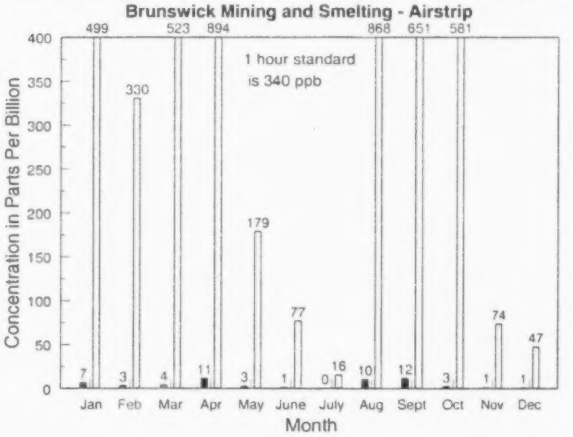
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Fraser - Cormier


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
15 103 13 132 19 103 18 124 17 154 14 164 8 130 7 80 7 156 6 111 11 244 9 90

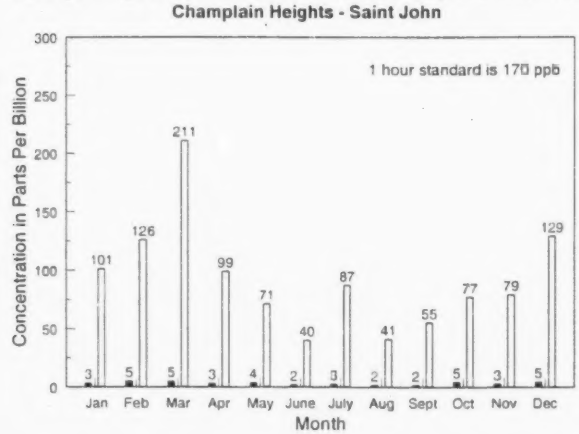
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Brunswick Mining and Smelting - Airstrip


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
7 499 3 330 4 523 11 894 3 179 1 77 0 16 10 868 12 651 3 581 1 74 1 47

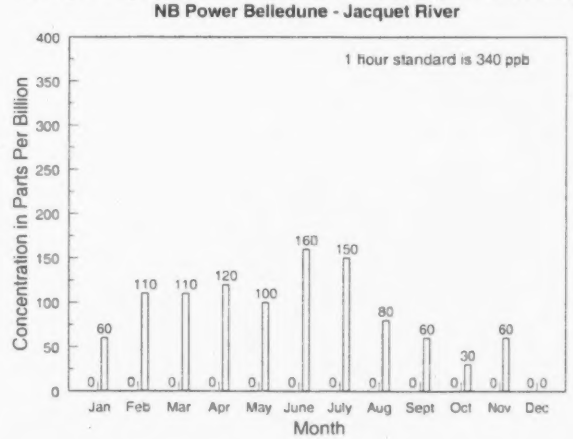
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Champlain Heights - Saint John


1 hour standard is 170 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
3 101 5 126 5 211 3 99 4 71 2 40 3 87 2 41 2 55 5 77 3 79 5 129

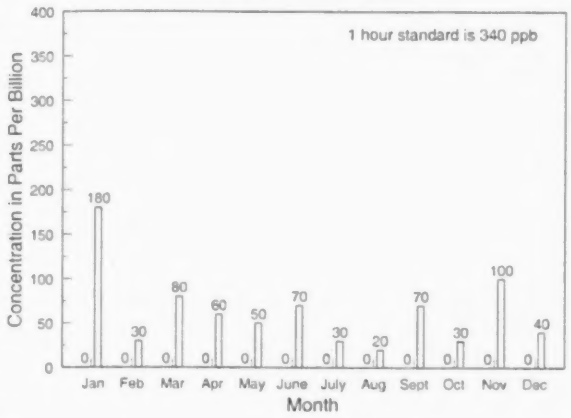
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Belledune - Jacquet River


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 60 0 110 0 110 0 120 0 100 0 160 0 150 0 80 0 60 0 30 0 60 0 0

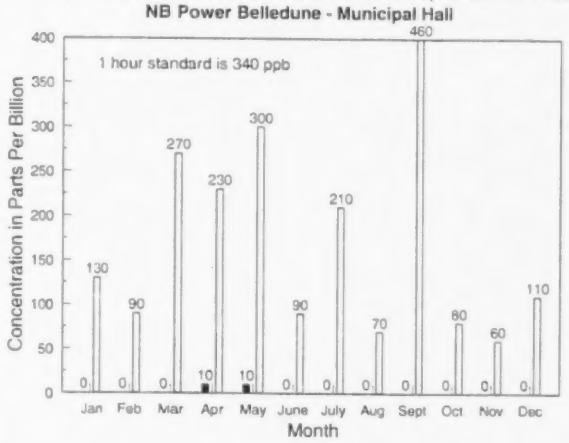
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Belledune - Madran


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 30 80 60 50 70 30 20 70 30 100 40
180

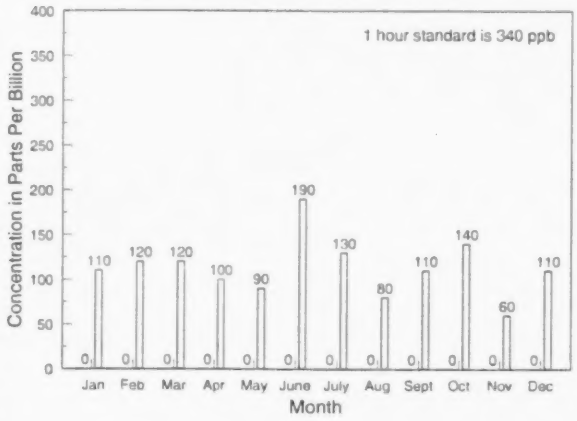
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Belledune - Municipal Hall


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
130 90 270 10 10 300 90 210 70 460 80 60 110
230

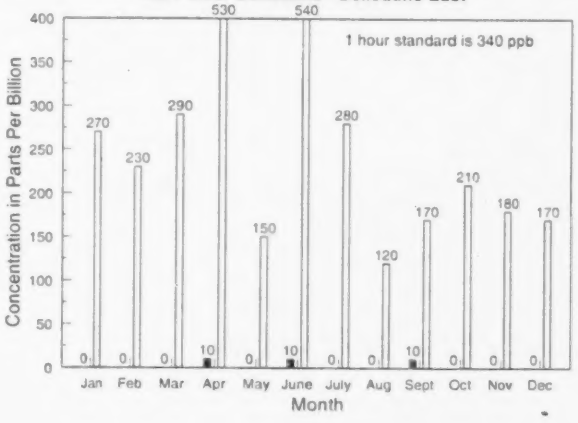
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Belledune - Pointe-Verte


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
110 120 120 100 90 190 130 80 110 140 60 110

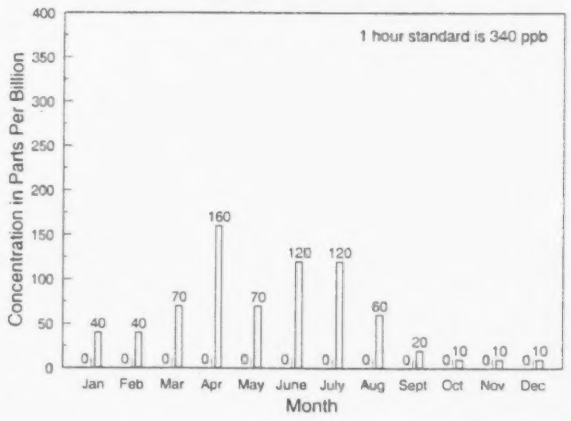
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Belledune - Belledune East


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
270 230 290 10 150 10 280 120 170 10 210 180 170
530 540

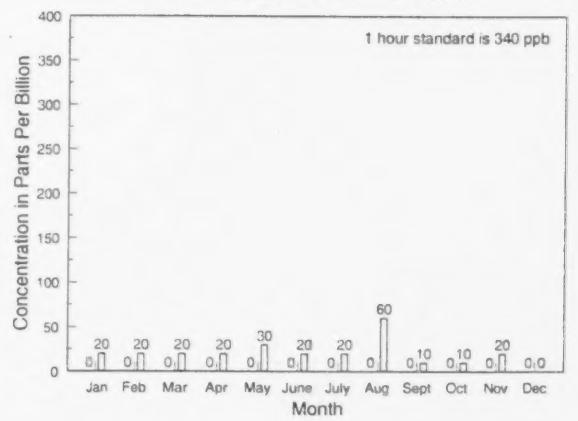
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Dalhousie - Bayview


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
40 40 70 160 70 120 120 60 20 10 10 10

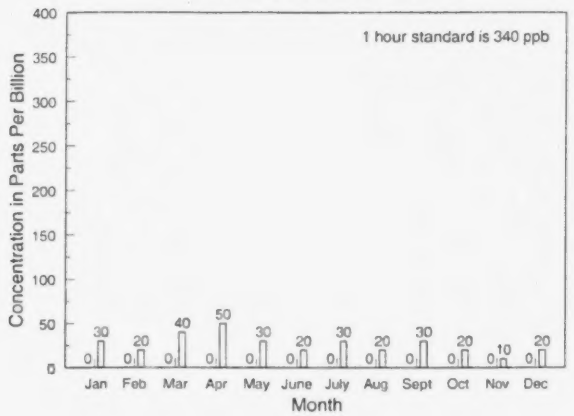
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Dalhousie - Dalhousie Tower


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
20 20 20 20 30 20 20 60 10 10 20 0

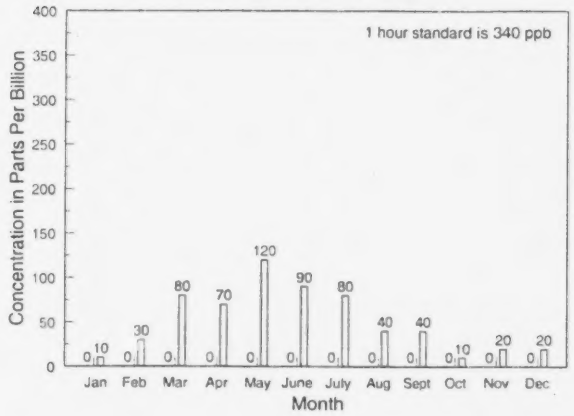
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Dalhousie - Charlo


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 30 0 20 0 40 0 50 0 30 0 20 0 30 0 20 0 30 0 20 0 10 0 20

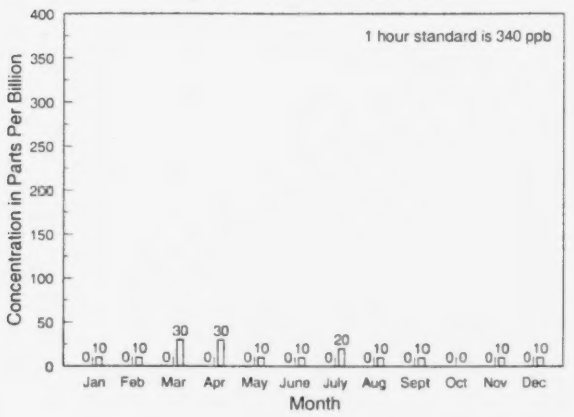
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Dalhousie - Mobile


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 10 0 30 0 80 0 70 0 120 0 90 0 80 0 40 0 40 0 10 0 20 0 20

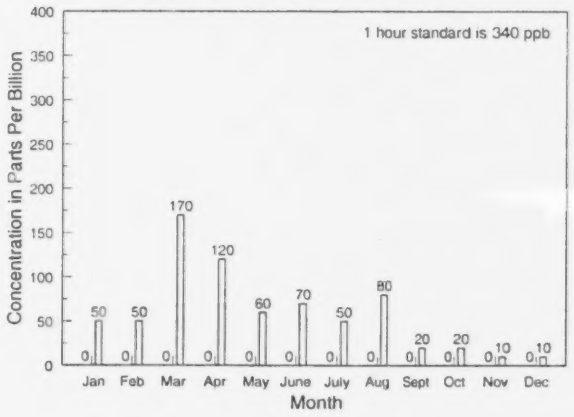
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Dalhousie - Pointe-a-la-Garde


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 10 0 10 0 30 0 30 0 10 0 10 0 20 0 10 0 10 0 0 0 10 0 10

Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Dalhousie - Point la Nim


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 50 0 50 0 170 0 120 0 60 0 70 0 50 0 80 0 20 0 20 0 10 0 10

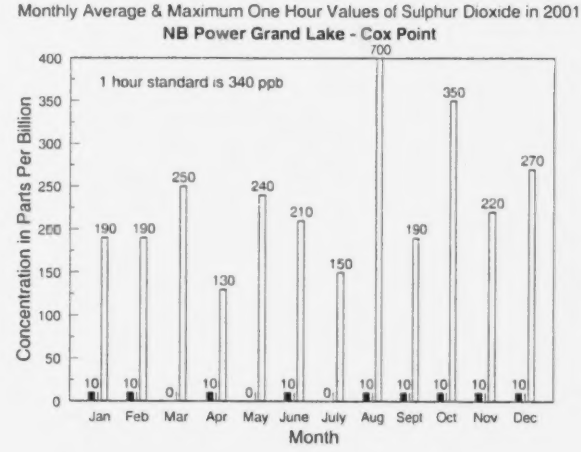
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Grand Lake - Bailey Point

1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 80 0 90 10 240 0 110 0 280 10 320 10 270 10 230 0 220 10 180 0 100 10 250

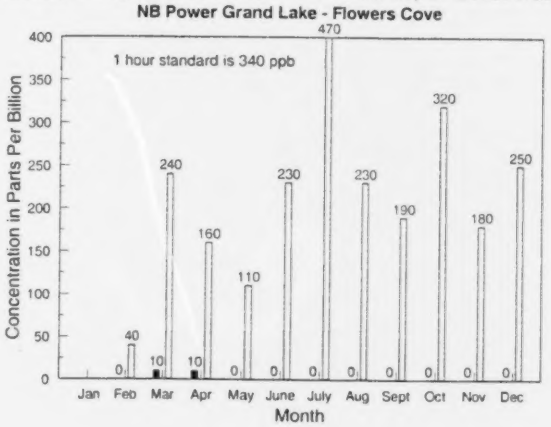
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Grand Lake - Cox Point


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
10 190 10 190 0 250 10 130 0 240 10 210 0 150 10 700 10 190 10 350 10 220 10 270

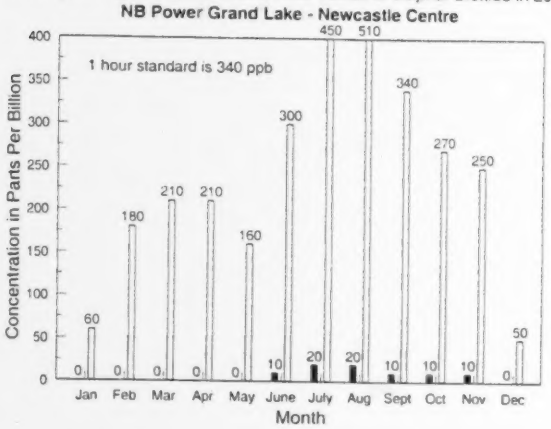
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Grand Lake - Flowers Cove


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 40 10 240 10 160 110 0 230 470 230 190 320 180 250

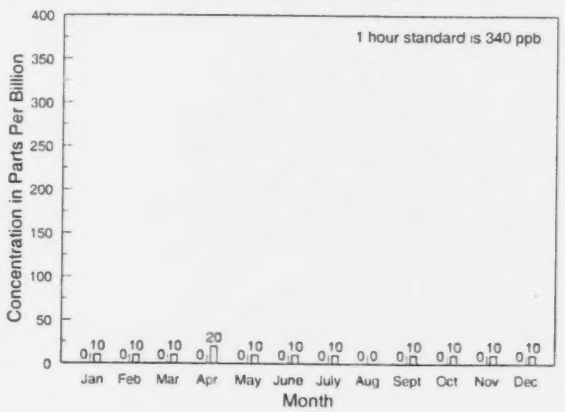
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Grand Lake - Newcastle Centre


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 60 180 210 210 160 300 450 510 340 270 250 50

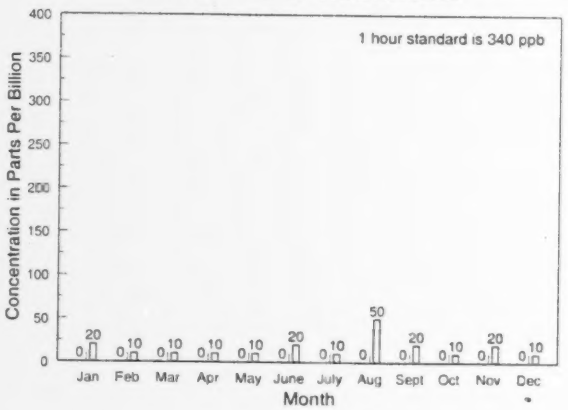
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Millbank - Rockcliff


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
0 10 10 10 20 10 10 10 0 10 10 10 10

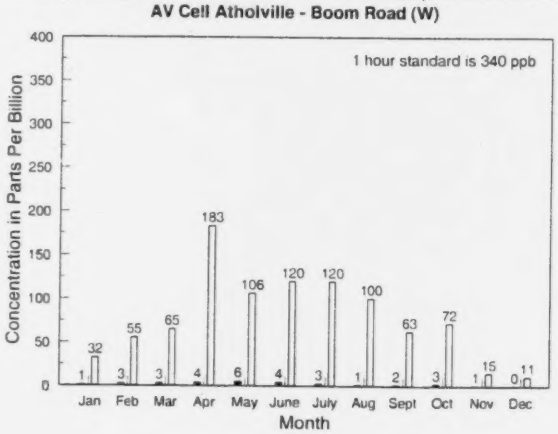
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

NB Power Millbank - Lower Newcastle


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
20 10 10 10 10 20 10 50 20 10 20 10

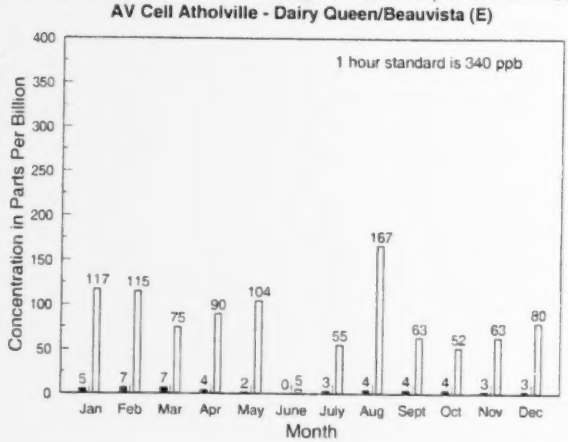
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

AV Cell Atholville - Boom Road (W)


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
1 32 3 55 3 65 4 183 6 106 4 120 3 120 1 100 2 63 3 72 1 15 0 11

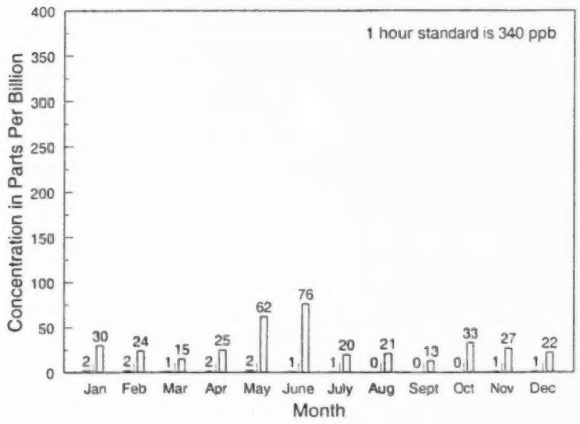
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

AV Cell Atholville - Dairy Queen/Beauvista (E)


1 hour standard is 340 ppb
Concentration in Parts Per Billion
Month
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
5 117 7 115 7 75 4 90 2 104 0.5 3 55 4 167 4 63 4 52 3 63 3 80

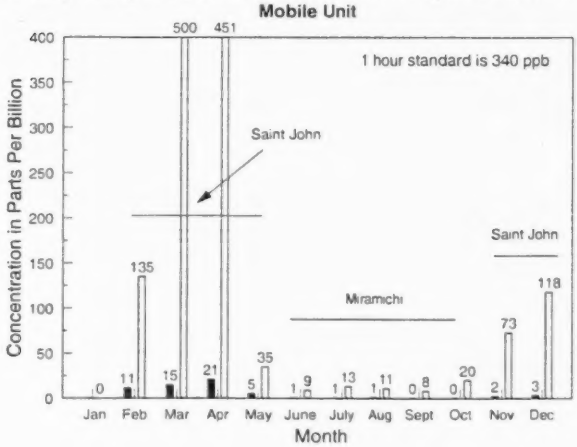
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Ste. Anne-Nackawic



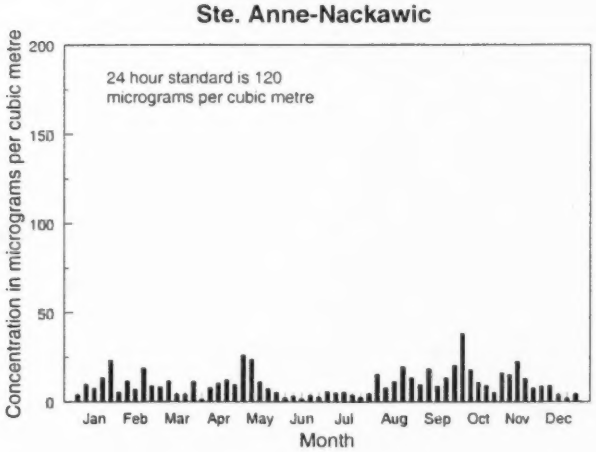
Monthly Average & Maximum One Hour Values of Sulphur Dioxide in 2001

Mobile Unit



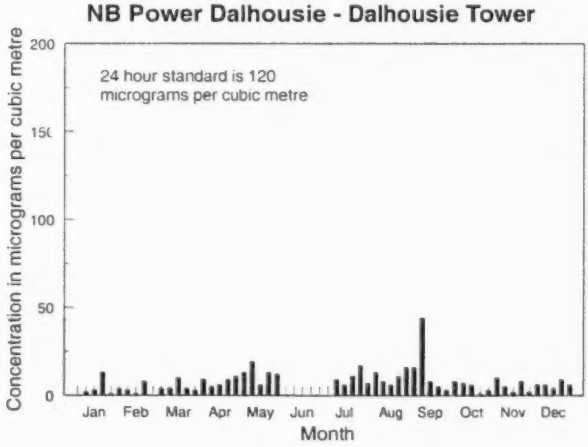
Daily TSP for 2001

Ste. Anne-Nackawic



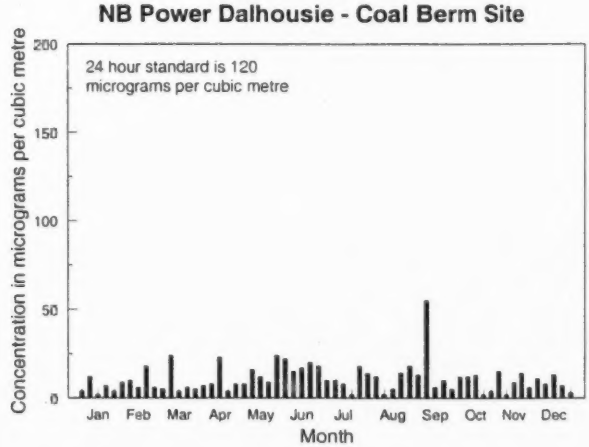
Daily TSP for 2001

NB Power Dalhousie - Dalhousie Tower



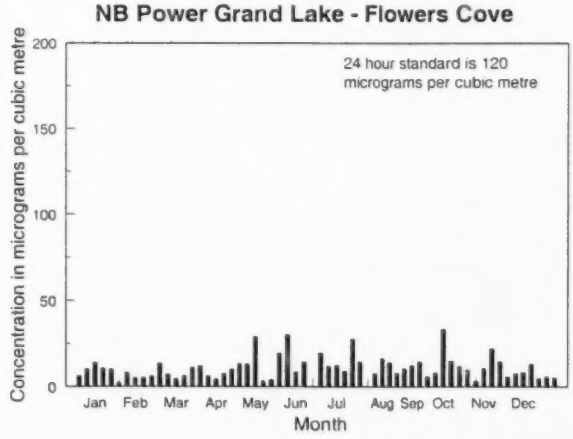
Daily TSP for 2001

NB Power Dalhousie - Coal Berm Site



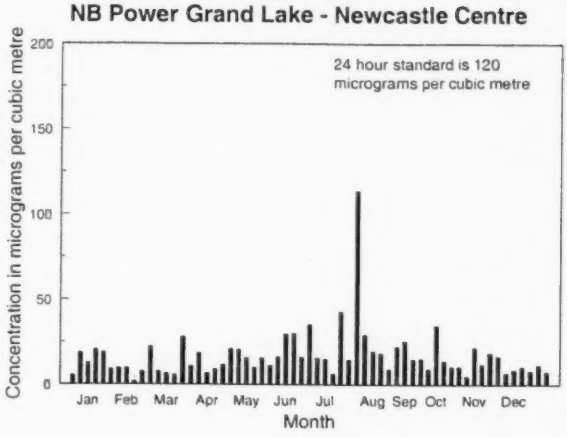
Daily TSP for 2001

NB Power Grand Lake - Flowers Cove



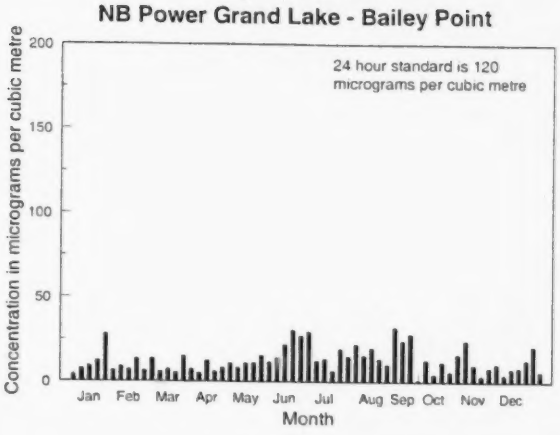
Daily TSP for 2001

NB Power Grand Lake - Newcastle Centre



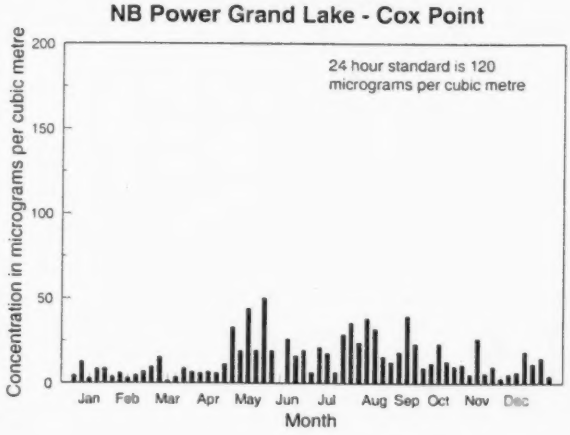
Daily TSP for 2001

NB Power Grand Lake - Bailey Point



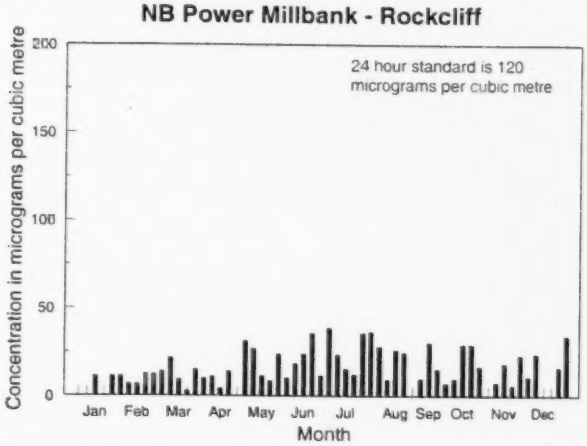
Daily TSP for 2001

NB Power Grand Lake - Cox Point



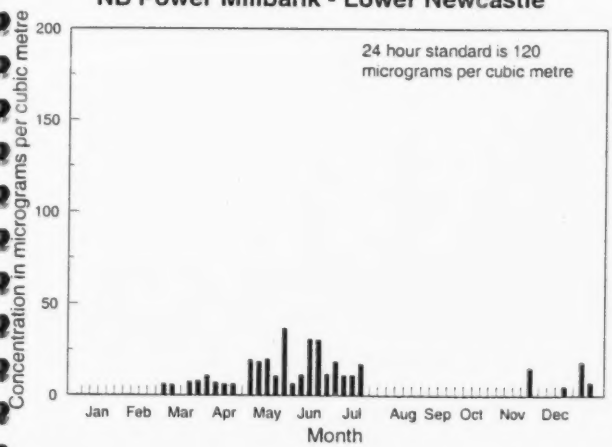
Daily TSP for 2001

NB Power Millbank - Rockcliff



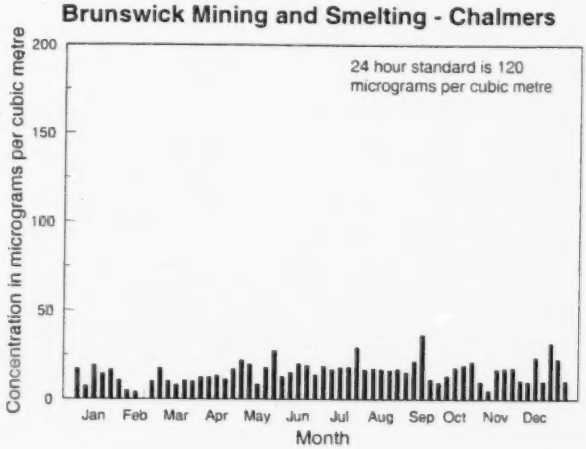
Daily TSP for 2001

NB Power Millbank - Lower Newcastle



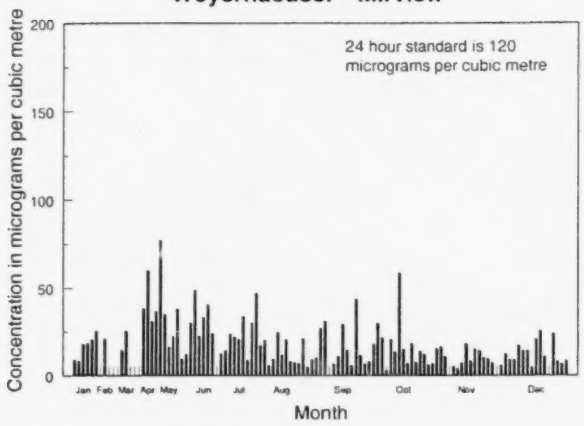
Daily TSP for 2001

Brunswick Mining and Smelting - Chalmers



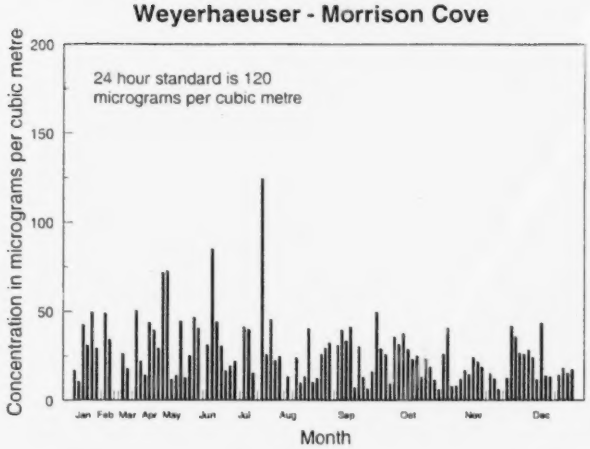
Daily TSP for 2001

Weyerhaeuser - Mirview



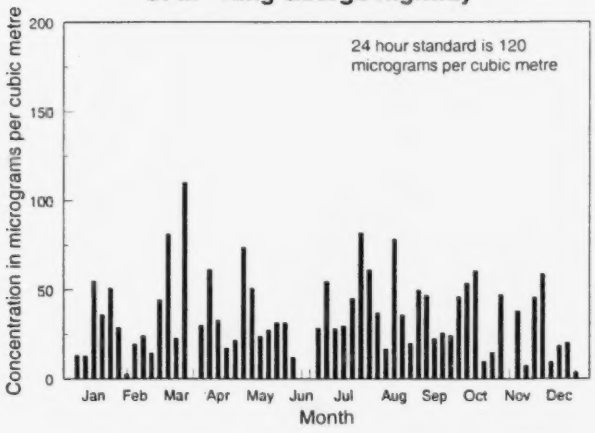
Daily TSP for 2001

Weyerhaeuser - Morrison Cove



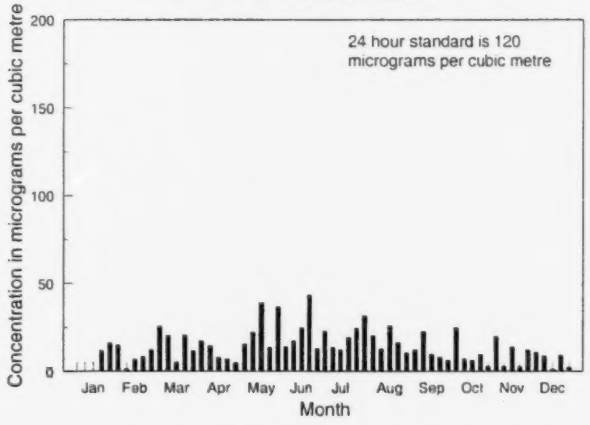
Daily TSP for 2001

UPM - King George Highway



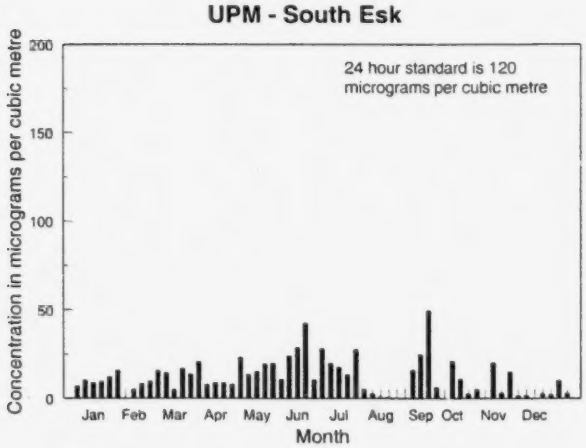
Daily TSP for 2001

UPM - Groundwood Mill



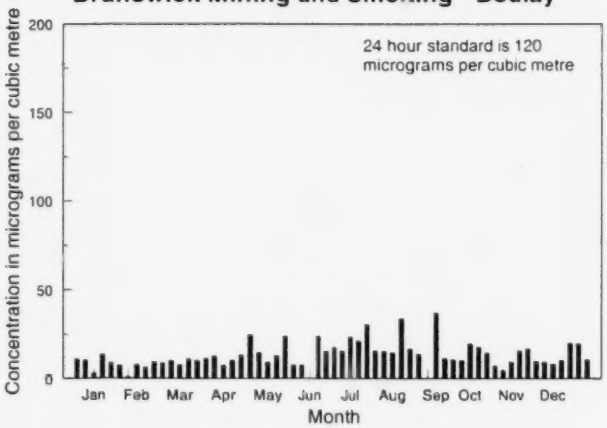
Daily TSP for 2001

UPM - South Esk



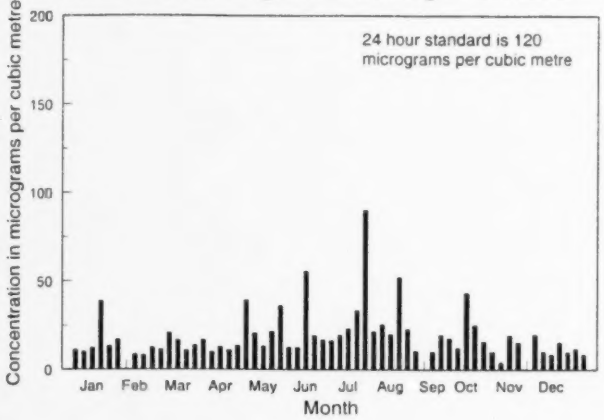
Daily TSP for 2001

Brunswick Mining and Smelting - Boulay



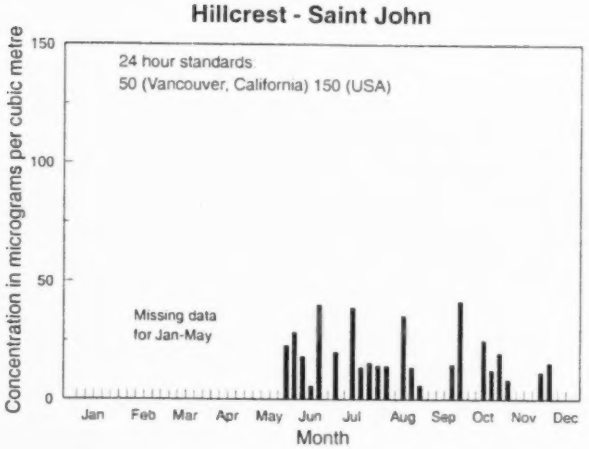
Daily TSP for 2001

Brunswick Mining and Smelting - Townsite



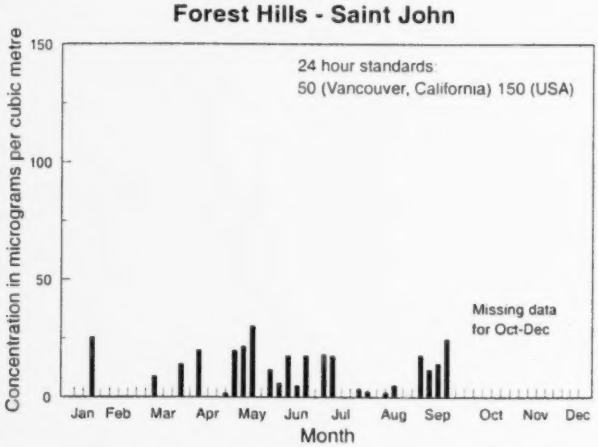
Daily PM10 for 2001

Hillcrest - Saint John



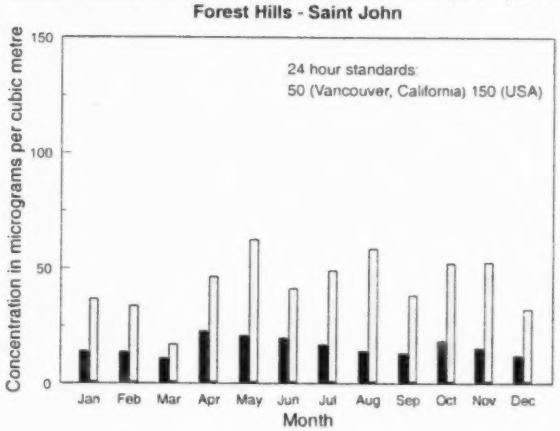
Daily PM10 for 2001

Forest Hills - Saint John

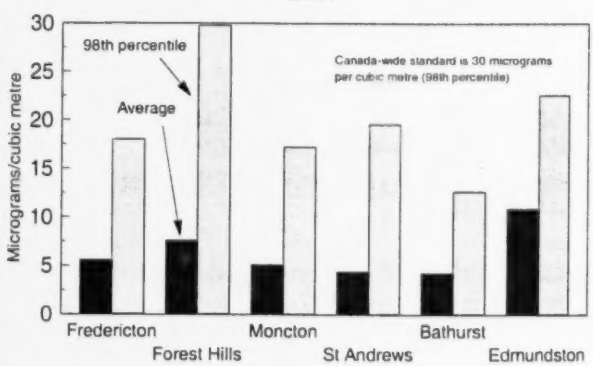


Monthly Average & Maximum 24-hour values of PM10 (TEOM) for 2001

Forest Hills - Saint John

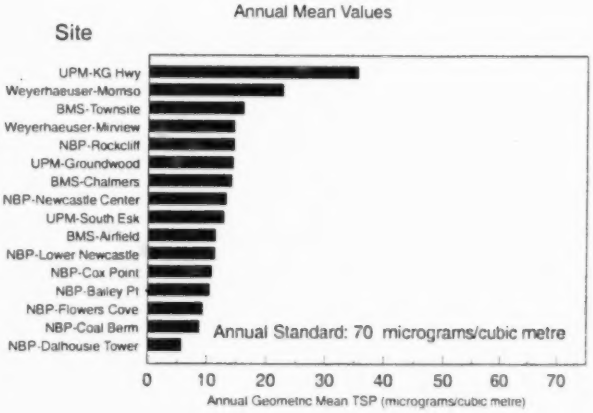


Annual average and 98th percentile PM2.5 by TEOM 2001



TSP Data - 2001

Annual Mean Values



REFERENCES

Aldighieri, A.M. (Ed.) 1998. Canadian Almanac and Directory. Micromedia, Toronto.

Bates, D.V., 1980. The health effects of air pollution. J. Respir. Disease 1: 29-37.

Blomberg, A., 1998. Respiratory effects of atmospheric pollutants: from science to the clinic. Presentation at the ERS/98 Symposium, Geneva, Switzerland, reproduced on the ENVENG internet mailing list, September 27, 1998.

CARB, California Air Resources Board, 1992. Initial Statement of reasons for rulemaking, identification of 1,3 butadiene. http://www.arb.ca.gov/toxics/summary/13butadi.htm

CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1987a. Review of national ambient air quality objectives for nitrogen dioxide; desirable and acceptable levels. Environment Canada, Conservation and Protection, Ottawa, 24 pp.

CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1987b. Review of national ambient air quality objectives for sulphur dioxide; desirable and acceptable levels. Environment Canada, Conservation and Protection, Ottawa, 31 pp.

CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1994. National ambient air quality objectives for carbon monoxide. Minister of Public Works and Government Services Canada, 161 pp.

CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1998. National ambient air quality objectives for particulate matter. Minister of Public Works and Government Services Canada.

CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1998. National ambient air quality objectives for carbon monoxide: Desirable, acceptable and tolerable levels. Minister of Public Works and Government Services Canada, Ottawa, 161 pp.

Commission for Environmental Cooperation, 1997. Long-range transport of ground-level ozone and its precursors: Assessment of methods to quantify transboundary transport within the northeastern United States and eastern Canada. Commission for Environmental Cooperation, Montréal, Québec, 108 pp.

Dann, T. F. 1994. PM10 and $PM_{2.5}$ Concentrations at Canadian urban sites: 1984-1993. Unpublished report of the Technology Development Directorate, Environment Canada, Ottawa.

Dann, T.F. 1998. Ambient air measurements of polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans in Canada (1987-1997). Unpublished report of the Technology Development Directorate, Environment Canada, Ottawa.

Delauriers, M., 1996. Canadian emissions inventory of criteria air contaminants (1990). Environment Canada, Ottawa; Environmental Protection Series, Report EPS 5/AP/7E.

Environment Canada, 1984. Hydrogen sulphide: Environmental and technical information for problem spills. Environmental Protection Service, Ottawa, 112 pp.

Environment Canada, 1985. Sulphur dioxide, Environmental and technical information for problem spills. Environmental Protection Service, Ottawa, 111 pp.

Environment Canada, 1998. National Pollutant Release Inventory, Canadian Environmental Protection Act, Summary Report, 1996. 226 pp.

EPAQS, 1994. Expert Panel on Air Quality Standards, Benzene, 1994. Department of The Environment, London.

HMSO, 2000. Environmental Protection, England. The Air Quality (England) Regulations 2000. 2000 No. 928. Her Majesty's Stationery Office, London. ISBN 0-11-099043-9. Also see: http://www.environment.detr.gov.uk/airq/airqual/index.htm.

Jaques, A., F. Neizert and P. Boileau, 1997. Trends in Canada's greenhouse gas emissions, 1990-1995. Environment Canada, Air Pollution Prevention Directorate, Ottawa.

Lalonde, Girouard, Letendre et Associés, 1993. PAH emissions into the Canadian Environment -1990. Report prepared for Environment Canada, Québec region.

Masters, G.M., 1997. Introduction to environmental engineering and science, 2nd Edition. Prentice-Hall, Upper Saddle River, NJ, 651 pp.

Multistakeholder NOx/VOC Science Program, 1997a. Canadian NOx/VOC Science Assessment: Ground level ozone and its precursors, 1980-1993. Report of the Data Analysis Working Group, Dann, T. and P. Summers, Eds. 295 pp.

Multistakeholder NOx/VOC Science Program, 1997b. Canadian NOx/VOC Science Assessment: Modelling of ground-level ozone in the Windsor-Québec City corridor and in the southern Atlantic region. Report of the WQC Corridor and Southern Atlantic Region Modelling Working Group. Venkatesh, S. and B. Beattie, Eds. 265 pp.

Multistakeholder NOx/VOC Science Program, 1997c. Canadian NOx/VOC Science Assessment: Report of the Health Objective Working Group, Wilby, K, G. Wood and D. Galarneau, Eds., 109 pp.

NADP, 2000. National Atmospheric Deposition Program. Web site: http://nadp.sws.uiuc.edu/

NEGECP, 1998. New England Governors and Eastern Canadian Premiers Mercury Action Plan. Conference of New England Governors and Eastern Canadian Premiers, Halifax, NS.

NESCAUM, 1998. Northeast States and Eastern Canadian Provinces Mercury Study: A framework for action. Editor Marika Tatsutani. NESCAUM, Boston, Mass.

OECD, 1995. Control of Hazardous Air Pollutants in OECD Countries, OECD, Paris.

Ritchie, I., 1991. Introduction to indoor air quality: a reference manual. Washington, D.C. US Environmental Protection Agency, EPA/400-3-91-003.

Statistics Canada, 1999. Information on transport statistics taken from website: http://www.statcan.ca/english/Pgdb/Economy/Communications/trade14.htm.

Stewart, R.L., 1975. The effect of carbon monoxide on humans. Ann Rev. Pharmacol. 15: 409-423.

Tordon, R., P. George, S.T. Beauchamp and K. Keddy, 1994. Source sector analysis of ozone exceedance trajectories in the Maritime region (1980-1993). Environment Canada, Atmospheric Environment Service, Report MAES 2-94, 60 pp.

Transport Canada, 1999. Information on transport statistics taken from web site: http://www.tc.gc.ca/tfacts/anre1998/TC9806DE.HTM.

US EPA, 1980. Significant harm levels for carbon monoxide. Research Triangle Park, NC, Office of Air Quality Planning and Standards.

WHO, 1987. Air Quality Guidelines for Europe, World Health Organisation, WHO Regional Publications, European Series No. 23, Copenhagen.

WHO, 1994. Chloroform. Environmental Health Criteria 163, World Health Organisation, Geneva.

WHO, 1996. Ethylbenzene. Environmental Health Criteria 186, World Health Organisation, Geneva.

WHO, 1997. Xylenes. Environmental Health Criteria 190, World Health Organisation, Geneva.

Wilson, R. and J. D. Spengler (Eds.), 1996. Particles in our air: concentrations and health effects. Harvard University Press, 259 pp.